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The primary purpose of these symposia is the dissemination of the latest research, development and demonstration information on process modifications, waste treatment by-product recovery and water reuse to industry, consultants, and government personnel. Twenty papers are included in this Proceedings as well as the final registration list.

These symposia will be continued; the Seventh is scheduled for April 7-9, 1976, in Atlanta, Georgia. If you are interested in participating or wish to receive additional information contact:

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April 9-11, 1975
Madison, Wisconsin

Co-sponsored by

NATIONAL CANNERS ASSOCIATION
Berkeley, California 94710

and

WISCONSIN CANNERS AND FREEZERS ASSOCIATION
Madison, Wisconsin

INDUSTRIAL ENVIRONMENTAL RESEARCH LABORATORY
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FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory - Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

The Sixth National Symposium on Food Processing Wastes was cosponsored with the National Canners Association and the Wisconsin Canners and Freezers Association. The primary purpose of these symposia is the dissemination of the latest research, development and demonstration information on process modifications, waste treatment, by-product recovery and water reuse to industry, consultants and government personnel. Twenty papers are included in this Proceedings as well as the final registration list.

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INTRODUCTORY REMARKS

Lt. Governor Martin J. Schreiber

It is with a great deal of pleasure that I welcome this National Symposium to Wisconsin. On behalf of the State, I wish you well in your work. We are well aware that our future development here may be significantly affected by the ideas exchanged at this symposium.

The welfare of Wisconsin, more than many other states, depends directly on the vitality of its agricultural sector. About 30 percent of Wisconsin's work force is in agriculture or agriculture-related jobs. For the future, we must have a healthy and expanding agriculture and food processing industry.

But food production and food processing is important for more than purely economic reasons. Next to world peace, world hunger is probably the paramount issue facing mankind.

The specter of a growing food crisis, underscored by widespread starvation in some areas, has focused the spotlight of world attention on America's vast food production potential. It is clear to people all over the world that America must bear much of the burden of feeding an increasingly hungry world.

Today, one Wisconsin farmer feeds 55 people, 13 of whom live in foreign countries. As production grows in efficiency and volume, hopefully we will be able to increase that number. But the efficiency and technology of the food processing industry must keep pace.

The growth and health of agriculture and the food processing industry will be critically important in the years ahead. But, before that growth can take place, we must realize that important limiting factors are at work.

First, we cannot sacrifice the quality of our water, land and air for economic growth. The quality of life in many smaller towns can be easily affected by one food processing plant which pollutes the air, or the water.

All of you here today are aware of this reality, and many of you have helped contribute technical solutions to the problem. I commend you for that work. But as the pressure to produce and process more food increases, we will have an even greater challenge for environmental vigilence.

Secondly, work is underway, in various areas of Wisconsin and other states, to bring new land into production. If past patterns are repeated, processors will follow production into these new areas. These new plants, if and when they are built, will offer important opportunities for many of you here today. You can meet the same environment constraints with new ideas and new technologies, free of the constraints of existing physical plant and machinery.

Third, here in Wisconsin particularly, we must realize that environmental protection affects not only the quality of life for citizens, but also the livlihood of many people. Tourism is the major industry for the Northern part of Wisconsin. We must make certain that future growth protects the beauty and the recreational resources which are the foundation of that important industry.

We have been relatively successful in the past in Wisconsin because a strong spirit of cooperation has existed between producers, processors and all levels of government. Generally, because of this cooperation we have not had significant problems balancing the needs of food processors against environmental needs. I hope that similar cooperation can exist here and throughout the Nation as the need for increased food production grows.

It is to all of you here today that we look for answers to these important questions. Your work, and your ideas, will determine the degree to which Wisconsin, and other States, will successfully grow with the demands of the future.

INVESTIGATION OF AN ANAEROBIC-AEROBIC LAGOON SYSTEM TREATING POTATO PROCESSING WASTES

Dr. James N. Dornbush*
Dwayne A. Rollag*
William J. Trygstad**

INTRODUCTION

Various methods of treating potato processing wastes have been utilized during the past years, however, very limited data are available in the literature demonstrating the effectiveness of an anaerobic-aerobic lagoon system for treating these wastes. Midwest Foods Corporation (formerly Fairfield Products, Incorporated) of Clark, South Dakota, presently utilizes such a system to treat the waste water generated from the production of frozen French-fried potatoes. The following discussion provides a case history of the successes and failures of the system.

When the potato processing plant was constructed prior to the 1970-71 season, relatively little consideration was given to design and operation of the waste handling system. The waste water treatment facilities consisted of a screen and 25-acre stabilization pond. After the initial operating season in 1970-71, numerous complaints regarding offensive odors from the system were received by company and state authorities. Data obtained in June 1971 revealed that the stabilization pond was severely overloaded. The five-day biochemical oxygen demand (BOD_5) of the liquid contents was 1180 milligrams per liter. Acting upon the complaints, state authorities directed the company to construct facilities capable of satisfactorily treating the wastes prior to the 1971-72 processing season.

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Waste water flows and characteristics had not been measured at the processing plant; consequently, empirical design was a necessity. After discussions with representatives of the state, EPA, and the Civil Engineering Department at South Dakota State University, the consulting engineers designed an anaerobic lagoon followed by a mechanically aerated basin proceding the existing stabilization pond. The anaerobic lagoon and aerated basin were hastily constructed by the company in one corner of the existing pond although aeration equipment was not installed until March 1972.

During the 1971-72 potato processing season, waste water flows and characteristics were studied[1] to evaluate the treatment system. Approximately 3500 gallons of water per ton of raw potatoes were used during that season and all units of the treatment system were severely overloaded, both hydraulically and organically. Removal efficiency of the partially completed units was low. The entire system operated anaerobically and nuisance odors continued to generate complaints. The high water usage in the plant coupled with unusually high rainfall caused excessive dike erosion and ultimate disposal of the waste water from the plant during the coming season was a serious concern.

The company instituted an intensive campaign of in-plant changes aimed at waste reduction and water conservation after the 1971-72 operations including the installation of a dry-abrasive peeler, elimination of the peel from the waste water, recirculation of flume water, and cooling water reuse plus numerous minor alterations. The anaerobic lagoon was covered with a two-inch layer of styrofoam plus a straw mat to conserve heat and control odors. The aerators were also operated continuously throughout the summer and the liquid contents of the stabilization pond were recirculated through the aerated lagoon to aid the recovery of the system and alleviate the odors.

Evidence of recovery of the system was first noticed in March 1973 and aerobic conditions prevailed in the stabilization pond at this time. The 1973-74 waste discharge permit, issued by the South Dakota Department of Environmental Protection, required the company to monitor its waste discharges and loadings to the various treatment units. Data collected through this monitoring program made it possible to determine the value of the anaerobic pond and the flow-through aeration basins for the treatment of potato processing wastes at little additional expense. Consequently, a more complete investigation of the anaerobic-aerated lagoon system was undertaken to determine both the condition of the treatment units prior to the 1973-74 processing season, and the loading and removal efficiency of the treatment units.

PLANT DESCRIPTION

Figure 1 is a flow diagram of the processing plant operations. The production line, approximately 600 feet in length, is basically a "straight-through" process. Initially, the raw potatoes are transferred from storage to the mudpit by fluming. Soil and small quantities of organic matter that settle in the mudpit are pumped, as "silt water", periodically to a waste-receiving pit while the flume water is recycled.

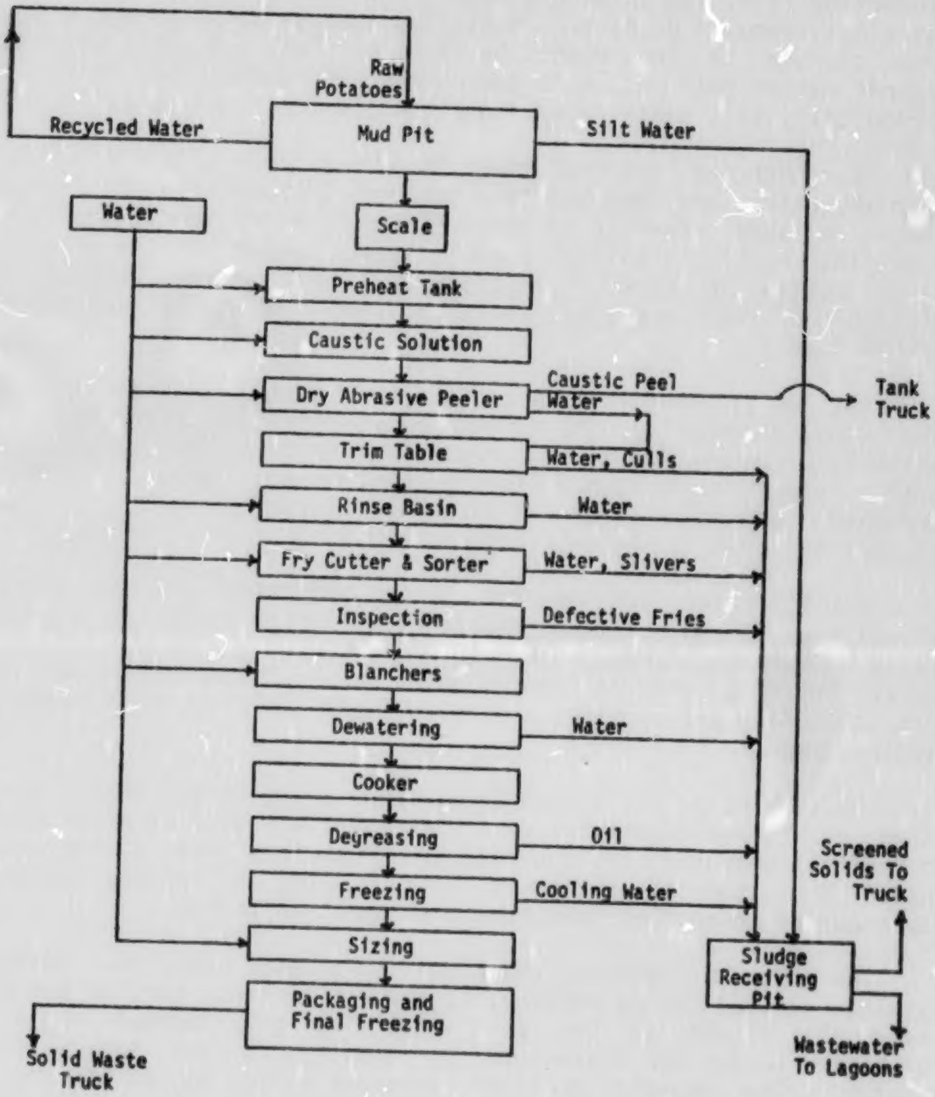
The potatoes are then conveyed over a scale into the preheat tank from which they are immersed in a hot caustic solution to loosen and soften the skin. Peeling is accomplished by a dry abrasive peeler. The resultant highly alkaline organic peel, which has the appearance of peanut butter, is pumped to a pit, or a 500-gallon tank truck and transported from the plant to be combined with corn silage and used as cattle feed.

The peeled potatoes pass on to a trim table where culls and eyes are removed manually. The trimmed potatoes pass to a holding tank from which they are augered to the French-fry cutters. Slivers and other small pieces unsuitable for packaging are removed by automatic separators and other defective fries are removed manually. Culls, eyes, slivers and defects are deposited in the waste flume.

The cut fries are treated by a blanching process to prevent discoloration and preserve the product. After the fries are dewatered using a vibrating screen, they are precooked in a deep-fat cooker. Excess cooking oil is removed using another vibrating screen. Wastes from blanching and cooking, including small amount of oil, reach the raw waste stream.

Subsequently, the French-fries enter a two-stage deep freeze and then are sized automatically. Wastes include cooling water during the defrosting operation and the rejected fries from the sizing operation which are used as livestock feed. After packaging, the fries are transported to another deep freeze to await shipment.

As shown in Figure 1, the flume silt-water and raw waste water streams evolved during sorting, cutting, blanching, cooking and freezing were all flumed to the waste-receiving pit, pumped to a 20-mesh vibrating screen and discharged by gravity to the lagoon treatment system. The caustic peelings, screened solids and solids produced by the sizing operation were removed from the plant by trucks for livestock feed.



Raw Potatoes
Recycled Water
Mud Pit
Silt Water
Water
Scale
Preheat Tank
Caustic Solution
Dry Abrasive Peeler
Caustic Peel Water
Tank Truck
Trim Table
Water, Culls
Rinse Basin
Water
Fry Cutter & Sorter
Water, Slivers
Inspection
Defective Fries
Blanchers
Dewatering
Water
Cooker
Degreasing
Oil
Freezing
Cooling Water
Sizing
Packaging and Final Freezing
Solid Waste Truck
Screened Solids To Truck
Sludge Receiving Pit
Wastewater To Lagoons

Figure 1. Potato processing plant flow diagram at Midwest Foods Corporation, Clark, South Dakota.

TREATMENT FACILITIES

The waste water treatment facilities of the plant consist of an anaerobic lagoon, aerated lagoon and stabilization pond all operated in series as represented schematically in Figure 2.

The anaerobic lagoon is approximately rectangular in shape having a mean width and length of 100 and 170 feet, respectively. Originally the lagoon had a liquid depth of 20 feet but this has been reduced substantially by the build-up of solids. The liquid volume was about 100,000 cubic feet. To preserve heat and control odors, the anaerobic lagoon was covered with a two-inch thick layer of styrofoam topped with a straw mat.

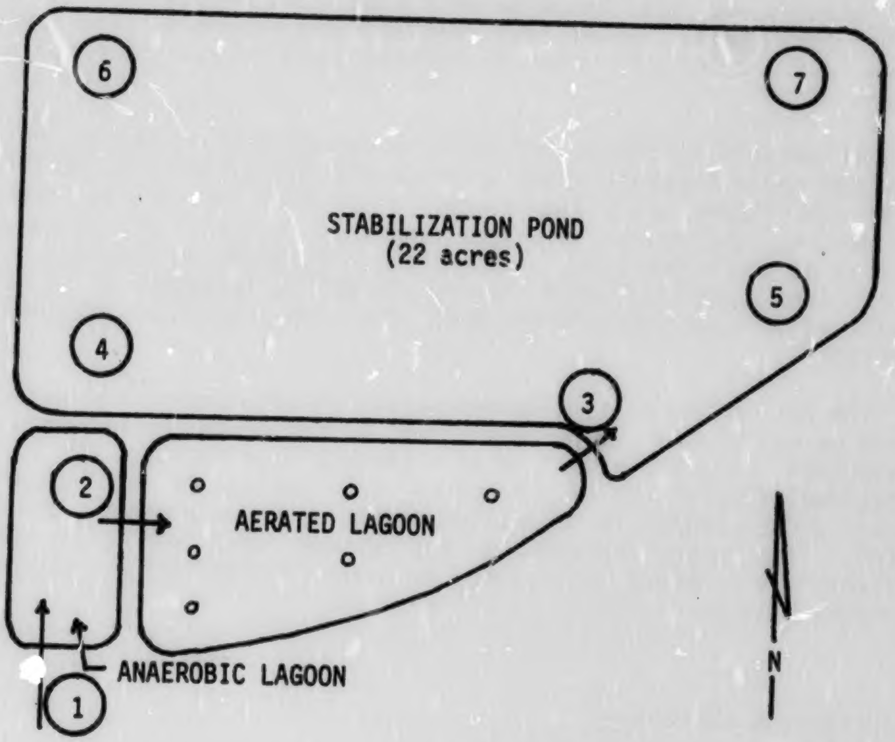
The aerated lagoon is triangularly shaped with a length of about 470 feet and a present volume of about 404,000 cubic feet. Originally, the aerated lagoon had a liquid depth of 12 feet but solids deposition has reduced the average depth to less than 10 feet. Six 25-horsepower floating aerators are located in the basin as shown in Figure 2. Waste water from the aerated basins flows by gravity to a 22-acre stabilization pond. Discharge from the pond is not practiced nor permitted.

The entire three-basin treatment system was constructed with little attention to inlet or outlet conditions of the units. Manholes were not constructed where pipes pass through the dikes; consequently, operational flexibility of the system is limited to controlling the number of aerators in operation as the waste water flows through the system. The dikes throughout the system were reconstructed and partially rip-rapped following serious erosion after the 1971-72 operating season.

INVESTIGATION PROCEDURES

The primary investigation reported herein was conducted during the period of August 1 to November 14, 1973, although plant processing operations were limited to a period of September 6 to November 14. During this period, the plant processed an average of 4.72 tons of raw potatoes per hour of operation or about 85 tons per day.

Samples were collected weekly from seven locations in the treatment system as shown in Figure 2. Raw waste, anaerobic lagoon and aerated lagoon effluent samples were composited from grab samples collected at two-hour intervals during the day shift. Because the discharge permit required sampling from each quadrant of the stabilization pond, four grab samples were analyzed individually from this source. Samples were



6
7
STABILIZATION POND
(22 acres)
5
4
3
2
AERATED LAGOON
ANAEROBIC LAGOON
1
N

Figure 2. Schematic flow diagram of the treatment system showing the sampling points.

refrigerated after collection and during transport to South Dakota State University where the analyses were performed. The time lapse between the end of sampling and arrival at the laboratory was less than two hours and analyses of the samples began immediately. A total of fifteen different determinations were performed on the waste waster samples, with most of the analyses conducted in accordance with Standard Methods.[2] Most analyses were performed weekly although a few were made only at monthly intervals.

Plant flows were measured using a three-inch Parshall flume installed between the vibrating screen and the anaerobic lagoon. Initially, a recorder was used to continuously measure flow; however, because of excessive vibration and solids accumulation in the float stilling well, the recorder was abandoned in favor of hourly manual flow measurements taken during the day shift when the plant was processing. Flume silt-water flow was estimated by recording the time of pump operation as the solids were pumped from the mudpit.

Details concerning the sampling and compositing procedures, the particular method employed for analyses of samples and techniques of measuring flow have been reported.[3]

CONDITION OF THE TREATMENT UNITS PRIOR TO THE 1973-74 CAMPAIGN

One of the objectives of the investigation was to determine if the anaerobic lagoon, aerated lagoon and stabilization pond had recovered from the overloaded conditions that existed from 1970-72. The contents of the stabilization pond were green instead of the pink that was evident during 1970-72 when anaerobic conditions prevailed. Whereas the pink coloration was indicative of the presence of purple sulfur bacteria which proliferate under anaerobic conditions, the green color demonstrated the presence of oxygen-producing algae which are normally present in a well functioning stabilization pond. Further indication that the stabilization pond was aerobic was the absence of any noticable odors emanating from the pond. The aerated lagoon was also free of odors. Slight odors were noted in the immediate vicinity of the anaerobic lagoon. Furthermore, gas bubbles were observed at the surface of the anaerobic lagoon which would be expected when anaerobic decomposition was occurring.

In addition to the visual inspection of the waste water treatment facilities, several analytical determinations were performed to evaluate the conditions of the system. The average results obtained from these analyses are presented in Table 1.

Table 1. AVERAGE ANALYTICAL RESULTS PRIOR TO THE 1973-1975 CAMPAIGN

Parameter	Anaerobic lagoon	Aerated lagoon	Stabilization pond
Dissolved oxygen, mg/l	-	4.5	8.1
ORP, mv	-358	+45	+63
NO_3-N, mg/l	0	61	0.05
NH_3-N, mg/l	133	0.31	0.85

The highly negative oxidation-reduction potential, zero nitrate-nitrogen and high ammonia-nitrogen concentrations shown in Table 1 for the anaerobic lagoon are results typical of anaerobic conditions. The values presented in Table 1 for the aerated lagoon and stabilization pond indicate that these units had returned to aerobic conditions prior to the 1973-74 processing season. The dissolved oxygen results should be considered approximate values because of an unexplained interference that occurred when the samples were fixed in the field. The positive oxidation-reduction potentials, low ammonia-nitrogen concentrations and presence of nitrates in both units provide additional evidence in support of the conclusion that both units were aerobic immediately prior to the 1973-74 processing season.

QUANTITY OF RAW WASTE STREAMS

From a frequency distribution plot of flows gaged on an hourly basis, the raw waste flow was 57 gpm or less 50 percent of the time. Ninety percent of the time, flow was less than 125 gpm. Highest flows occurred during plant clean-up, flushing of a plugged flume or during defrosting operations. The average daily flow ranged from a low of 54,720 gpd to a high of 142,560 gpd. The average waste water flow during the day shift processing period was about 64 gpm. Assuming this average to be representative of the entire processing period, a discharge of 92,160 gallons per day would result. Approximately 4.72 tons of raw potatoes were processed per hour of operation. Based on the average flow of 64 gpm, approximately 813 gallons of waste water were produced per ton of raw potatoes processed.

Silt-water was also pumped to the anaerobic lagoon on an average of once per day. The average pumping time was 11.8 minutes at a rate of 418 gpm resulting in 4,932 gallons of silt-water produced daily. Based on an average input of 85 tons of raw potatoes per day, approximately 58 gallons of silt-water were produced per ton of raw potatoes. It should be noted, however, that during the 1973-74 season unusually clean potatoes were received at the plant.

RAW WASTE CHARACTERISTICS

The quantity of raw potatoes processed per day varied considerably, ranging from 41 to 122 tons with an average of 85 tons. The characteristics of the raw waste were also highly variable. On at least one occasion, cautic peel was discharged to the waste stream causing maximum concentrations of suspended solids (SS), and chemical oxygen demand (COD) and a very high pH.

The average characteristics (except pH) of the raw waste are included in Table 2. The pH of the raw waste ranged from 9.2 to 11.6. The median pH value was 10.6 which was lower than the median pH of 11.4 obtained in the 1971-72 study,[1] undoubtedly the result of the reduction in caustic peel allowed to enter the waste stream. Temperature of the raw waste varied from 23 degrees to 27 degrees C with the average being about 25 degrees C.

The impact of the new peeling process and the implementation of extensive water conservation measures were clearly evident when the BOD_5, SS and COD concentrations shown in Table 2 were compared with the 1971-72 study. The BOD_5 and COD concentrations shown in Table 2 were about 70 percent higher than determined two years earlier while SS concentrations were about 225 percent higher. However, waste water flows during this period had been reduced from 3500 to 813 gallons per ton of potatoes processed. These concentrations would be considered excessive for the potato processing plant had it not been for the reduced flows. The BOD_5, COD and SS loadings were 40.5, 84.6, and 67.7 pounds per ton of raw materials processed, which are quite representative of the industry.

Total Kjeldahl nitrogen (TKN) and inorganic phosphorus tests were performed to determine if sufficient nutrients were present in the raw waste to support biological growth. The most commonly quoted requirement of the BOD:N:P ratio for aerobic biological treatment is 100:5:1 while the raw waste water from the plant had a ratio of 100:7.1:26.7. It would appear that adequate nutrients to support aerobic biological growth were present although nitrogen deficiencies might occur during periods of extreme quality variation.

Analyses of the flume silt waste pumped daily to the waste stream were limited to solids determinations. For five samples of the silt water, mean concentrations were 14,044 milligrams per liter of SS and 61.1 milliliter per liter of settleable suspended solids after a 23-hour settling time.

Using average SS concentration of 14,044 milligrams per liter and the average daily volume of 4,932 gallons, it was calculated that 578 pounds of silt (6.8 pounds per ton of potatoes) were pumped to the anaerobic lagoon per operating day. Assuming this silt would occupy an average volume of 61.6 milliliters per liter in the anaerobic lagoon after settling, an average of 40.5 cubic feet of compacted silt was produced per operating day during the 1973-74 season. At this rate, a normal production year of about 245 days would produce approximately 9,925 cubic feed of compacted silt resulting in a 9.8 percent reduction in anaerobic lagoon.

Table 2. MEAN CONCENTRATIONS AT TREATMENT UNITS

Determination[a]	Raw waste (screened)	Anaerobic lagoon	Aerated lagoon	Stabilization pond
Temperature, °C	25.1	22.7	12.9	11.7
pH - units (median)	10.6	7.1	8.85	9.5
BOD_5	5,978	1,573	251	59
COD	12,489	4,692	815	471
SS	9,993	2,200	712	149
Total residue	17,127	7,554	6,017	6,678
Conductivity, µmho/cm	6,801	6,480	6,740	8.567
ORP, mv	-	-396	-52	-11.6
Volatile acids	-	956	-	-
Total alkalinity	2,590	3,853	3,527	5,038
DO	-	-	1.2	14.2
Phosphorus	1,277	706	450	260
TKN	308	180	44.4	22.1
NO_3-N	0.22	0	56	0.16
NH_3-N	29.3	50.2	5.1	0

[a] All units in mg/l unless otherwise noted.

TREATMENT ACCOMPLISHMENTS

Table 2 also includes the mean concentrations of samples representing the effluent of the anaerobic lagoon and the aerated basin as well as the contents of the stabilization pond. Becuase flow is straight through the units, comparison of the concentrations will demonstrate the removals accomplished by the individual treatment units.

Anaerobic Lagoon

During the period of the investigation, the average retention time provided by the anaerobic lagoon was 8.2 days. Conditions for anaerobic treatment of the wastes were certainly satisfactory in that the median pH was 7.1 with a range of 6.8 to 7.4 and the temperature averaged 22.7 degrees C. Volatile acids ranged from a maximum of 1,380 milligrams per liter early in the investigation to 570 milligrams per liter on the last sample collected, with a mean concentration of 976 milligrams per liter. The mean volatile acids to alkalinity ratio was 0.25 and the oxidation-reduction potential (ORP) was -396 mv. These conditions have been described[4] as satisfactory for the continued conversion of the organic material in the lagoon to carbon dioxide and methane.

It is important to note that the raw waste pH was reduced from 10.6 to about neutrality (pH of 7.1) in the anaerobic lagoon. The buffering capacity of the system seemed to be highly effective even when the pH of the raw waste was 11.4 to 11.6.

Temperature of the anaerobic lagoon was above 21 degrees C throughout the investigation, only a few degrees lower than that of the raw waste. This temperature is well above a recommended minimum value of about 15 degrees C at which anaerobic biological activity is sharply curtailed. During the 1971-72 investigation of the system when the anaerobic lagoon was uncovered, the average temperature was about 12 degrees C. Thus, the styrofoam-straw cover presently employed appears to have contributed substantially to maintaining a more suitable temperatue in the anaerobic lagoon.

The loading rates and removal efficiencies for the anaerobic lagoon are included in Table 3.

These loading rates are substantially higher than those generally recommended for design of anaerobic lagoons. For example, the BOD_5 loading of 45.5 pounds per 1,000 cubic feet per day was three times higher than that recommended for anaerobic lagoons in South Dakota. However, the unit obtained a 73.7 percent removal of BOD_5 with nearly comparable removals of COD and SS.

Table 3. LOADING RATE AND REMOVAL EFFICIENCY TREATMENT UNITS

Location	Loading rate	Removals, %
Anaerobic lagoon, lbs/1,000ft^3/day		
BOD_5	45.5	73.7
COD	90.0	62.4
SS	76.0	77.9
Aerated lagoon, lbs/1,000 ft^3/day		
BOD_5	3.0	81.8
COD	8.9	82.6
SS	4.2	67.6
Stabilization pond, lbs/acre/day		
BOD_5	8.8	76.5
COD	28.5	42.2
SS	24.9	79.1
Lagoon system, lbs/acre/day		
BOD_5	-	99.0
COD	-	96.2
SS	-	98.5

[a] Based on the average daily flow of 92,160 gallons.

Although the removals for the anaerobic lagoon were based on samples collected over a comparatively short period and did not include data during a severe winter period, the removals appear representative of the unit during winter conditions. For example, thirteen samples collected during the current season from October 1974 through March 1975 had mean removals of 77.5 and 7.1. percent, respectively, for BOD_5 and SS.

Sufficient inorganic nutrients were present in the anaerobic lagoon effluent to support aerobic biological activity as indicated by an average BOD_5:N:P ratio of 100:25:90. Whereas the raw waste BOD_5:N:P ratio was 100:7.1:26.7, indicating a possible nitrogen deficiency at certain times, the BOD_5:N:P ratio present in the anaerobic lagoon effluent reveals that the anaerobic lagoon conserved the inorganic nutrients discharged to it. The increased nitrogen fraction was probably due to the reduction in carbon (BOD) brought about through the escape of carbon dioxide and methane from the degradation of nitrogen-containing compounds. Because of the higher cellular growth rates and commensurate requirement for nitrogen, an aerobic treatment unit would probably not bring about a similar conservation of nitrogen. Therefore the use of an anerobic lagoon appears to be of considerable value in providing a BOD_5:N:P ratio suitable for biological treatment of potato wastes which might otherwise have been nitrogen deficient.

Aerated Lagoon

During the investigation, the aerated lagoon provided an average retention time of near 33 days, substantially longer than would normally be considered in design of a similar unit. Undoubtedly, this long retention time was the result of the reduction of waste flows through water conservation measures within the plant prior to the investigation.

Maintaining adequate dissolved oxygen in the aerated lagoon was a problem throughout the investigation. Although the mean concentration of dissolved oxygen was 1.2 milligrams per liter, on two occasions dissolved oxygen was zero when at least one of the six 25-horsepower aerators was not operating. Consequently, it is likely that an oxygen deficiency existed periodically in the aerated lagoon although odors from this unit were not a problem.

Low temperatures in the aerated lagoon were not a problem during the investigation with an average of 12.9 degrees C; however, with extremely cold weather, icing difficulties have occurred. In mid-January 1975, a severe blizzard occurred and the floating aerators iced to the extent that several completely overturned. During the one and one-half months that the aerators were inoperative, the aerated basin became completely covered with ice, turned anaerobic and effluent quality from the basin approached that of the anaerobic lagoon. When the aerators were placed in operation, extremely noisome odors persisted for a few days; however, about ten days later the BOD_5 of the effluent was reduced to 450 milligrams per liter and the odor problem was eliminated.

The loading rates and removal efficiencies of the aerated lagoon are included in Table 3. These loading rates were low and, consequently, average removal of BOD_5, COD and SS were high, 81.8, 82.6 and 67.6 percent, respectively. From the SS reduction, it is obvious that the aerators do not provide adequate mixing of the basin contents and that sedimentation plays an important part of the overall removals of the unit.

Stabilization Pond

The mean concentrations of the contents of the stabilization pond are included in Table 2. The BOD_5 and SS concentrations of the pond exceeded the limits extablished for discharge to surface waters in South Dakota and, without additional treatment, could not have been discharged. However, because of the low hydraulic loading to the pond, no direct discharge from the pond existed. The unit has served effectively as an evaporation pond for ultimate disposal of the waste water throughout the five years of service and only during the summer of 1972 was it necessary to employ some spray irrigation for the purpose of reducing the lagoon volume.

Prolific algal concentrations were the cause of the high SS concentrations in the pond and dissolved oxygen was always present in the pond with a mean concentration of 14.2 milligrams per liter. It appears from the total Kjeldahl and ammonia nitrogen results that the algae have utilized nearly all the available nitrogen in the pond.

During the 1973-74 processing season, the BOD_5 loading to the stabilization pond was low, averaging only 8.8 pounds of BOD_5 per day. Consequently, overall reductions of BOD_5 in the pond were 76.5 percent (Table 3). By contrast, COD removals were only 42.2 percent, probably because of the high algae concentrations.

Lagoon System

The removals of the individual units and the lagoon system as a whole are presented in Table 3 comparing the influent and effluent concentrations. It will be observed by BOD_5, COD and SS removals for the entire system were all in excess of 96 percent.

To emphasize the relative importance of the individual units, however, the removals based upon the raw waste load are shown in Figure 3. From these pie graphs it is obvious that the anaerobic lagoon is the principal unit of the system accomplishing nearly 75 percent of the overall removal. Furthermore, the anaerobic lagoon during the period of this investigation operated essentially free of objectionable odors.

Odors from the stabilization pond have been the primary problem for the waste system and these were severe for the first two years when little attention had been given to water conservation and waste recovery. The water used at the plant contains a concentration of sulfates in excess of 400 milligrams per liter, and the production of hydrogen sulfide no doubt intensifies the nuisance odors. When the stabilization pond turned pink in 1971, probably as a result of photosynthetic sulfur bacteria as described by Sletten,[5] a marked reduction in nuisance odors occurred. This pink color persisted until aerobic conditions were established in the stabilization pond the following summer.

It is not suggested that a treatment system of the nature described would be equally successful for all similar potato processing plants. The success of the overall system can, however, be attributed primarily to the anaerobic lagoon. Even after the anaerobic-aerated lagoon components were added to the existing stabilization pond, at least a year was required before the anaerobic lagoon was functioning properly. Because of time limitations, little consideration had been given to providing the seed organisms required to rapidly establish an active population of methane-forming organisms necessary to break down the wastes without producing odors. During the time period between processing campaigns, active anaerobic digestion was established naturally, and this time period when processing wastes do not enter the system appears highly beneficial toward recovery of the entire system.

SUMMARY AND CONCLUSIONS

This investigation of the treatment system for the potato processing wastes at Midwest Foods Corporation, Clark, South Dakota, covered a three and one-half month period. During this time, analytical determinations and flow measurements were utilized to calculate loadings and removal efficiencies for the various treatment units. The following conclusions were drawn:

1. Immediately prior to the 1973-74 processing season, aerobic conditions prevailed in the aerated lagoon and stabilization pond indicating that these units had recovered from the overloaded conditions that existed prior to that time.

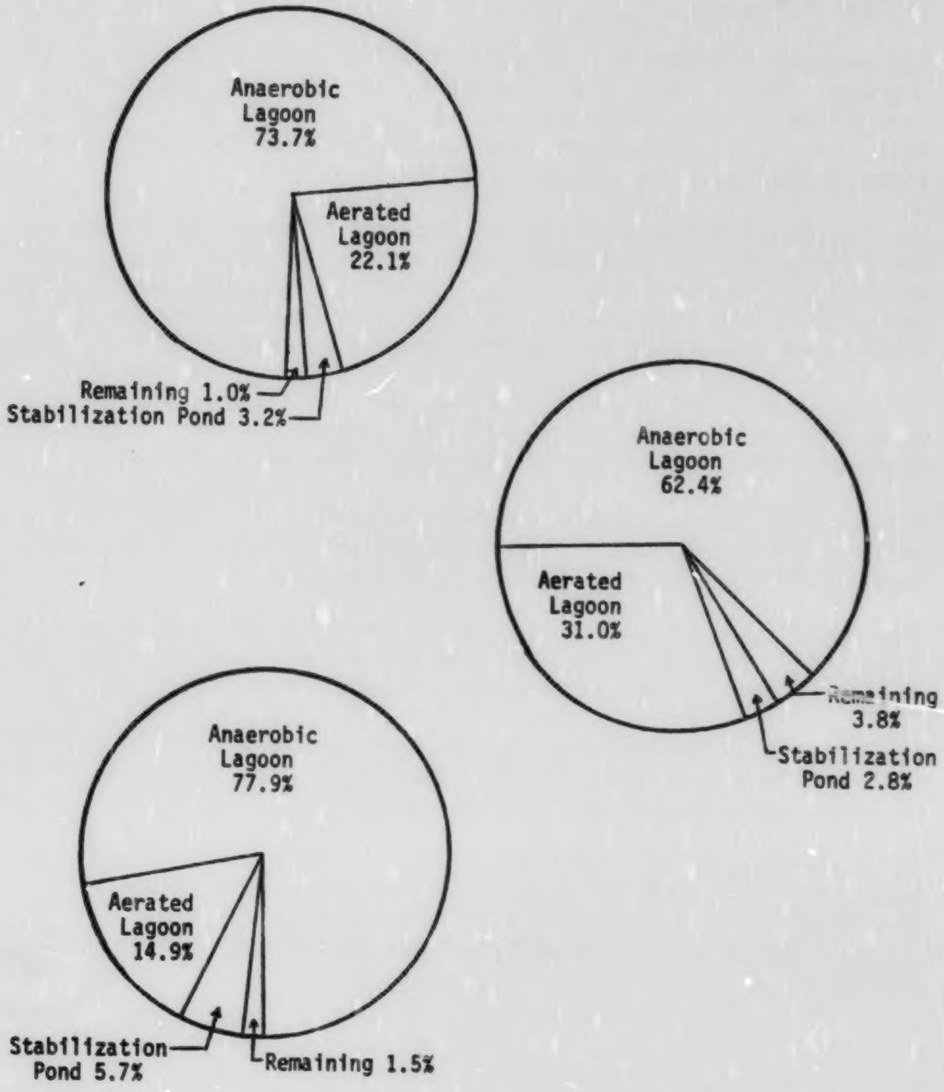


Figure 3. Average removals obtained by the various treatment units based on raw waste characteristics.

2. Utilization of a new dry-caustic peeling process and extensive in-plant water conservation had reduced the water usage from 3,500 gallons per ton of raw potatoes to approximately 813 gallons per ton.

3. The anaerobic lagoon was an effective treatment unit in which average BOD_5 and SS removals of 74 and 78 percent, respectively, were obtained despite an average BOD_5 loading rate of 45.5 pounds per 1,000 cubic feet per day, over three times higher than the recommended design value.

4. The styrofoam-straw cover on the anaerobic lagoon was effective in maintaining an adequate temperature in the lagoon and helpful in controlling odors. Although slight odors were detected in the vicinity of the anaerobic lagoon, they were not considered a nuisance during the period of investigation.

5. It is evident from the BOD_5:N:P ratios obtained that it is advantageous to use an anaerobic lagoon prior to aerobic treatment if conservation of inorganic nutrients is desired.

6. The aerated lagoon, operating well within the BOD_5 loading range, performed within anticipated efficiencies removing 82 percent of the BOD_5 and 68 percent of the SS.

7. The stabilization pond was operating at about 50 percent of its design BOD_5 loading. The BOD_5 and SS removal efficiencies in this unit were 77 and 79 percent, respectively.

8. During this investigation, overall average removal efficiencies of the treatment system of 99, 98.5 and 96.2 percent were obtained for BOD_5, SS and COD respectively.

9. Silt build-up at the present rate of 40.5 cubic feet per operating day, could eventually decrease the volume of the anaerobic lagoon, thus reducing the retention time in the lagoon and possibly the efficiencies obtained by the anaerobic lagoon.

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UTILIZATION OF CHITOSAN FOR RECOVERY OF COAGULATED BY-PRODUCTS FROM FOOD PROCESSING WASTES AND TREATMENT SYSTEMS

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INTRODUCTION

Chitosan is a polymer composed of glucosamine residues which are linked by β,1-4 glycosidic bonds as shown in Figure 1. It is manufactured from shrimp and crab wastes by the following sequence of steps: (1) extraction of mineral components in dilute hydrochloric acid, (2) extraction of protein components with dilute alkali, (3) deacetylation of the chitin exoskeleton (poly N-acetylgucosamine) with hot concentrated alkali, and (4) recovery and drying. The time and temperature conditions for hydrolyzing the acetyl group especially influence the characteristics of the chitosan product. Shorter times, higher temperatures, and exclusion of air generally produce chitosan products with less degradation of the polymer structure and higher viscosities.[1,2] The various factors affecting the properties of the chitosan product including different manufacturing conditions and molecular weight distribution need considerable study.

This laboratory has been investigating for the past two years the effectiveness of chitosan for treatment of various food processing wastes. Results have shown chitosan to be an effective coagulating

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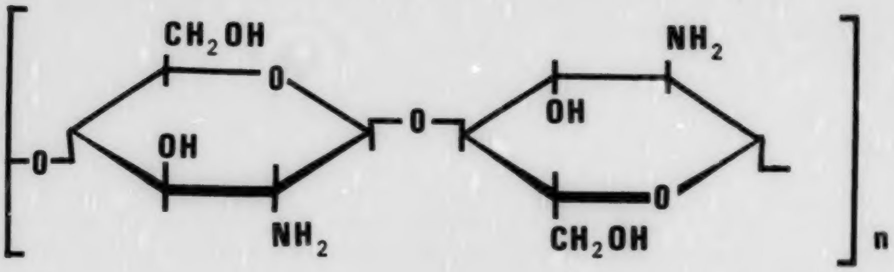
CH$_2$OH
O
OH
NH$_2$
O
NH$_2$
OH
O
CH$_2$OH
n

Figure 1. Structure of chitosan.

agent for reduction of suspended solids in processing wastes from vegetable, poultry, and egg breaking plants.[3,4,5] It has been tested also on cheese whey, seafood wastes, meat wastes, and activated sludge. Chitosan has been particularly effective with protein-containing wastes. Recovery of the coagulated by-products obtained by treatment with chitosan and utilization of these by-products in animal feeds is a potential option for treatment of concentrated wastes from food processing plants. This paper reports results of pilot scale testing of chitosan for coagulation and centrifugal recovery of activated sludge at a brewery and at a vegetable cannery. The major vegetables canned at the latter plant are pimentos, leafy greens, and green beans. Proximate and amino acid analyses of coagulated by-products from brewery sludge, vegetable cannery sludge, and egg breaking wastes are reported. The results of a preliminary study on the physiological effects of chitosan in rat diets are presented.

METHODS

Chitosan was obtained from Food, Chemical, and Research Laboratories, Inc., Seattle, Washington, under a program funded by the National Sea Grant Program to supply research quantities of material. The crude chitosan product typically contained 91 percent chitosan, 5 to 8 percent water, and 0.5 to 0.8 percent ash. Solutions of 20 grams per liter crude chitosan in 1 percent acetic acid has viscosities of 140 to 180 cps at 20 degrees C as measured with a Brookfield Viscometer.

Effects of chitosan on conditioning of brewery sludge were evaluated with Buchner funnel filterability test.[6] Laboratory studies on conditioning were conducted over a six-week period on a total of 13 samples received from the brewery.

The centrifuge used in conjuntion with the brewery sludge experiments was a Sharples BD-1 unit from Pennwalt Sharples, Warminster, Pennsylvania. During polymer tests, activated sludge from the main plant clarifier underflow was fed into the continuous centrifuge at a rate of 26 to 32 gallons per minute. The characteristics of the sludge remained constant throughout these experiments. The feed rate and settings were optimized for the centrifuge to operate with the aid of a polymer for conditioning the sludge. Control tests without polymer were also made at these settings. The bowl speed of the centrifuge was 3,250 to 3,300 rpm and the pond depth was held constant. The speed of the conveyor which removed the sludge cake was varied to give a speed differential of from 3 to 17 rpm. Chitosan was injected into the centrifuge as a solution of 2 grams per liter crude chitosan in 0.7 percent acetic acid.

Tests on activated sludge from vegetable canning wastes were conducted with a pilot-scale centrifuge, Model STM-1000, from Western States Machine Company, Hamilton, Ohio. Thickened sludge from the main plant clarifier underflow was pumped into the batch centrifuge at a desired feed rate until the breakpoint where the capacity of the basket was exceeded. The centrifuge speed was 3,200 rpm which corresponded to 1,740 times gravity. Chitosan as a solution of 5 grams per liter in 1 percent acetic acid or 1 gram per liter in 0.2 percent acetic acid was injected into the basket through a spray nozzle by the action of a tubing pump. Synthetic polymers WT-2680, WT-2660, WT-2640, WT-3000, Natron 86, Floc 534, Floc 535, Betz 1190, Betz 1160, and Atlasep 105c were applied as solutions of 1 gram per liter in water.

Centrifugal studies at a brewery and a vegetable canning operation were evaluated by assaying suspended solids in the sludge feed and centrate and by determining total solids in the sludge cake.[7] The flow rates of the centrate in the brewery study, or the sludge feed at the vegetable canning plant, were determined as well as the polymer feed rates for each experiment and set of samples. This data was necessary to calculate the concentration of chitosan in the sludge feed.

Coagulated sludge samples for analysis were freeze-dried to avoid heat damage to protein components. These were analyzed for crude protein,[8] fat, ash, and in some cases fiber.[9] Protein components extractable with alkali were determined by a biuret method developed by Herbert _et al._ for microbial protein.[10] Amino acid composition of acid hydrolysates was determined with a Durrum Amino Acid Analyzer System.[11] Tryptophan in brewery sludge was determined by the microbiological method of Henderson and Snell.[12] Tryptophan analyses were performed by WARF Institute, Inc., Madison, Wisconsin.

Physiological effects of chitosan in rat diets were explored in a preliminary experiment. Weanling Sprague-Dawley male rats (five per treatment) were fed _ad libitum_ for five weeks on a standard casein diet[13] in which chitosan at levels of 0, 0.5, 1.0, 2.0 and 5.0 percent replaced a corresponding amount of sucrose. The animals were sacrificed at the end of the experimental period; and total hemoglobin[14] and hematocrit, using micro-hematocrit tubes, were determined. The livers were removed and liver weights determined.

DISCUSSION

Brewery Sludge

Suspended solids in the thickened brewery sludge ranged from 8,000 milligrams per liter to 15,000 milligrams per liter. Figure 2 shows the results of a typical Buchner funnel filterability test. The optimum ratio of chitosan to suspended solids appeared to be between 0.6 and 0.8 percent.

First tests with the full-scale continuous Sharples centrifuge at the brewery were conducted to determine the optimum differential speed between the bowl and the sludge conveyor. Figure 3 shows that a differential setting of 3 rpm resulted in a dry cake containing nearly 10 percent solids, but the centrate contained over 9,300 milligrams per liter suspended solids compared to 11,000 to 12,000 milligrams per liter in the sludge feed. Treatment with chitosan at a differential setting of 3 rpm resulted in the capture of 30.7 percent of the suspended solids compared to 22.4 percent capture in the control trial with no polymer. Increasing the differential speed to 12 rpm increased the capture of suspended solids to approximately 70 percent. A differential of 17 rpm and treatment with 76 milligrams per liter chitosan (0.64 percent) resulted in a sludge cake containing 7.3 percent total solids. The centrate contained 602 milligrams per liter suspended solids which corresponded to 94.9 percent capture.

The effects of varying the chitosan concentration while maintaining a differential speed setting of 17 rpm are shown in Figure 4. Using a ratio of 0.6 to 0.8 percent chitosan to suspended solids resulted in a sludge cake containing approximately 7.5 percent solids and a centrate containing less than 600 milligrams per liter suspended solids. This corresponds to 95 percent capture of suspended solids from the sludge feed which contained approximately 12,000 milligrams per liter suspended solids.

Vegetable Canning Sludge

Initial tests to determine the optimum amount of chitosan showed (Figure 5) that a ratio of chitosan to suspended solids in the sludge feed of 0.2 to 0.3 percent resulted in the centrate containing less than 200 milligrams per liter suspended solids compared to approximately 16,000 milligrams per liter in the sludge feed. This amounted to approximately 99 percent capture of suspended solids from the sludge which was fed into the centrifuge at a rate of 8 to 9 liters per minute. The total solids content of the sludge cake was 9.7 percent

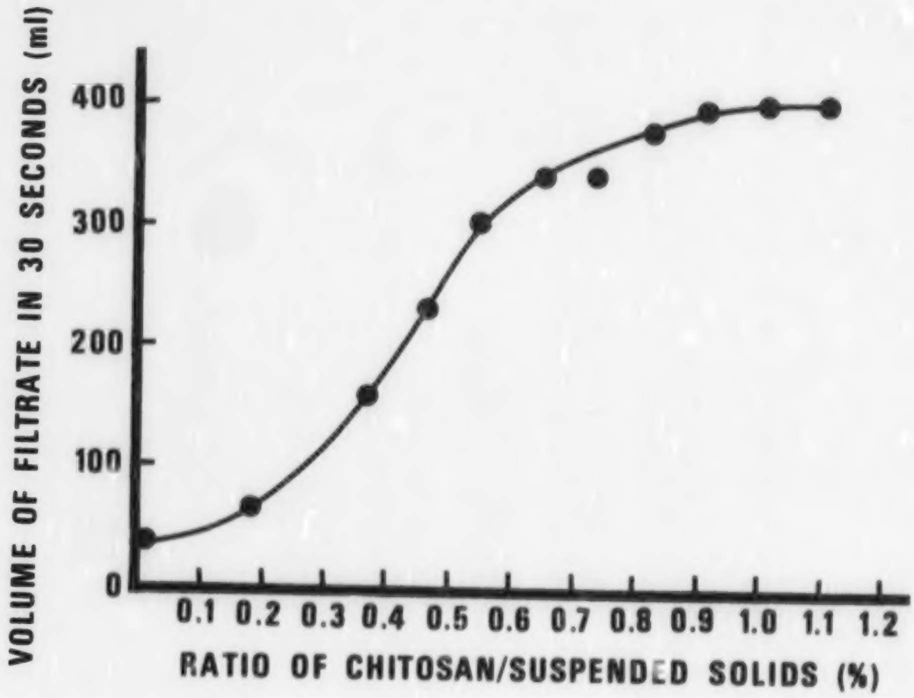

Figure 2. Buchner funnel filterability test to evaluate conditioning of activated sludge from brewery with chitosan.

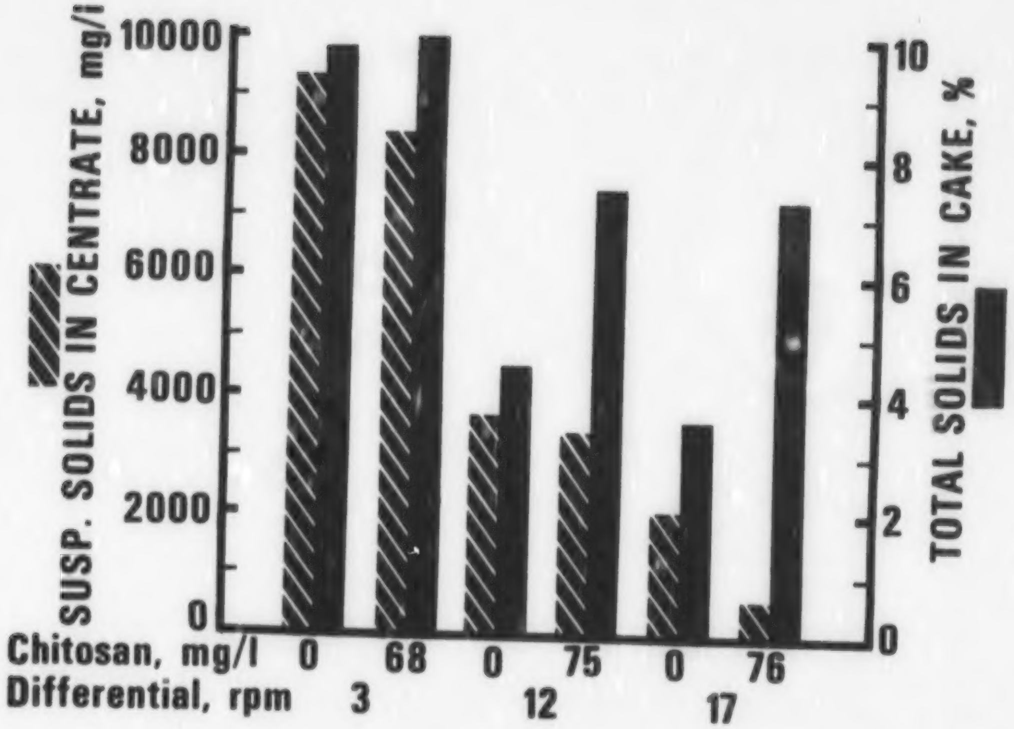

Figure 3. Effects of speed differential between bowl and conveyor of continuous centrifuge and of chitosan concentration on suspended solids in centrate and total solids in sludge cake from brewery activated sludge.

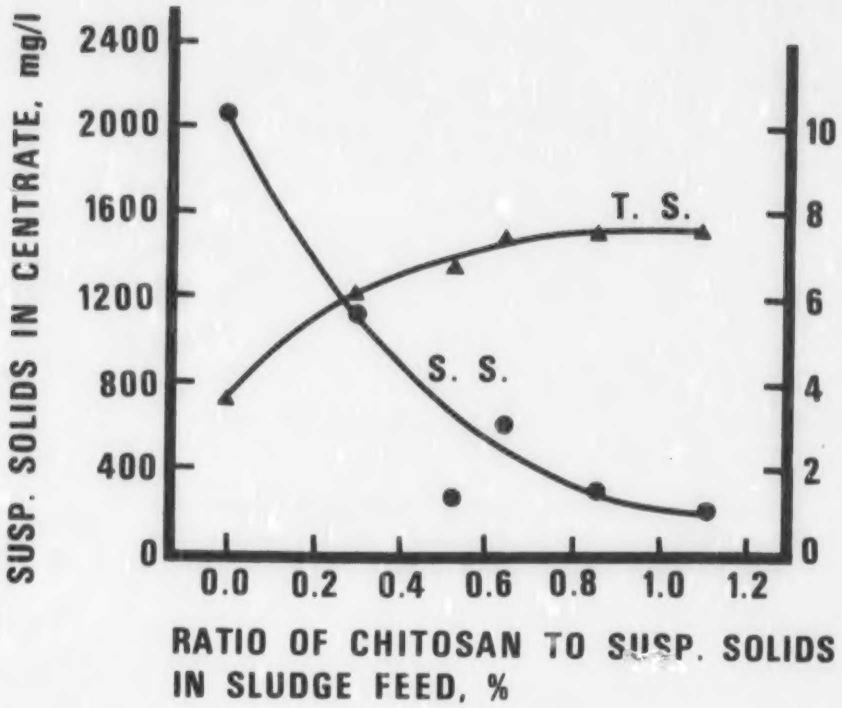

Figure 4. Effects of chitosan concentration on suspended solids in centrate and total solids in sludge cake obtained by continuous centrifugation of brewery activated sludge. (Centrifuge bowl speed was 3,300 rpm and differential was 17 rpm.)

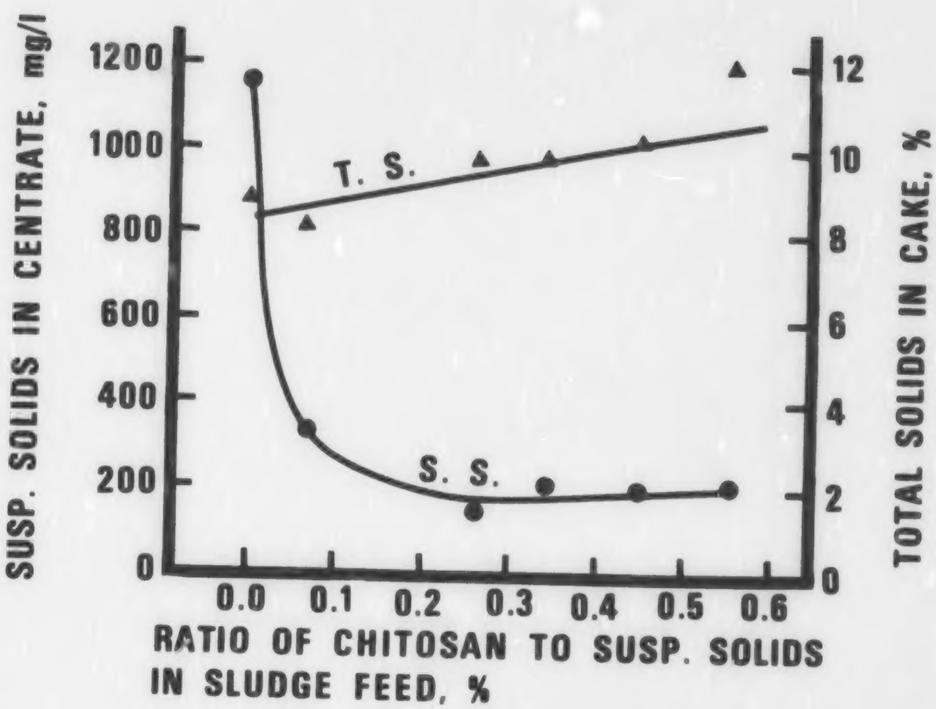

Figure 5. Effects of chitosan concentration and suspended solids in centrate and total solids in sludge cake obtained by batch centrifugation of vegetable cannery activated sludge. (Sludge feed rate was 8 to 9 l/min; centrifuge speed was 3,200 rpm.)

corresponding to a chitosan concentration of 40 milligrams per liter or a ratio of 0.27 percent chitosan to suspended solids.

The effects of varying the sludge feed rates and the presence or absence of 40 milligrams per liter chitosan on suspended solids in the centrate and total solids in the cake are shown in Figure 6. At sludge feed rates below 10 liters per minute, the capture of suspended solids (92 to 99) was greater than the capture at higher feed rates. Total solids in the sludge cake was approximately one percentage point higher when chitosan was added regardless of the feed rate. At a feed rate of 12.75 liters per minute, the control trial without polymer resulted in 4,500 milligrams per liter suspended solids in the contrate (72.2 percent capture) and 8.4 percent total solids in the sludge cake. Treatment with 40 milligrams per liter chitosan reduced suspended solids to 280 milligrams per liter (98.3 percent capture) and increased total solids in the cake to 9.2 percent. Thus, chitosan effectively increased solids capture while permitting the sludge to be fed into the centrifuge at a higher flow rate.

Table 1 shows a comparison of chitosan and ten commercially available polymers. All were cationic polymers except WT-3000 which is an anionic polyelectrolyte. All of the polymers, when applied to the sludge feed at 40 milligrams per liter, resulted in a capture of 93 percent or more of the suspended solids compared to 87.5 percent in the control. The lowest suspended solids and turbidity levels in the centrate were effected by chitosan, WT-2660, Natron 86, and Atlasep 105c. The first three of these were chosen for further evaluation. Table 2 shows a comparison of chitosan, WT-2660, and Natron 86 applied at 10, 20, and 40 milligrams per liter to the vegetable sludge. Experiment No. I was conducted using a sludge feed rate of 8.6 liters per minute while suspended solids in the feed ranged from 10,000 to 18,000 milligrams per liter. Increasing the concentration of each polymer reduced the suspended solids in the centrate and increased capture of suspended sludge solids accordingly. Experiment No. II was done at a higher sludge feed rate (13.3 to 14 liters per minute), but the concentration of suspended solids in the feed were lower (1,500 to 9,200 milligrams per liter) because sludge has been removed from the clarifier for disposal prior to this set of experiments. However, the same trend was apparent as in Experiment No. I. The results of both experiments showed that chitosan was competitive with, if not superior to, the synthetic polymers tested for conditioning of activated sludge to aid in centrifugal recovery of the sludge solids.

It remains to be seen if the price of chitosan will also be competitive. It is estimated from our experience that chitosan would have to sell for $1 to $2 per dry pound to be competitive with the price of other commercially available polymers. Food, Chemical, and Research Laboratories, Inc., continue to produce chitosan in their pilot plant in

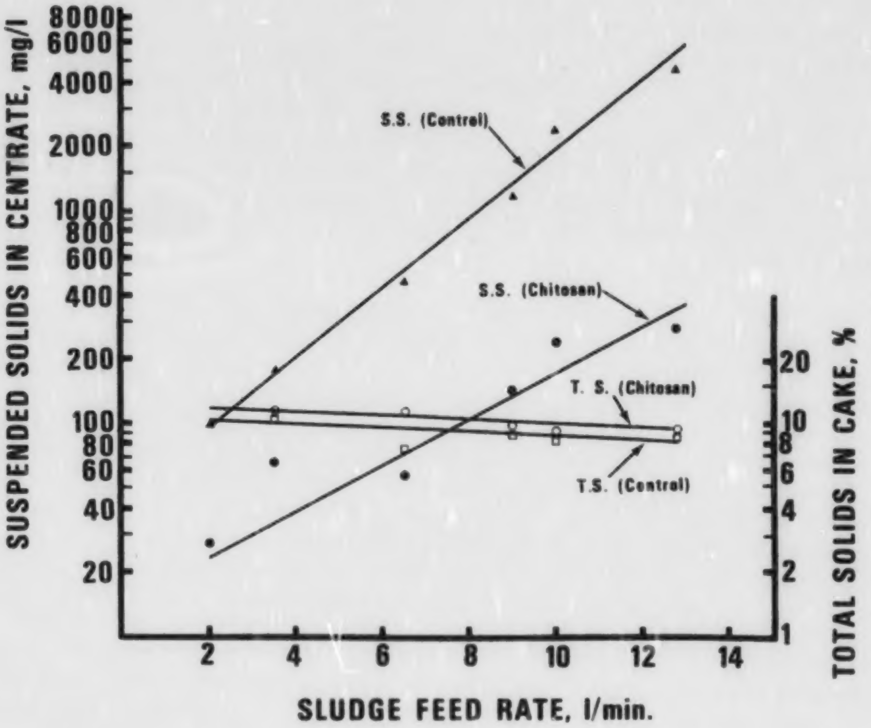

Figure 6. Effects of sludge feed rate with and without 40 mg/l chitosan on suspended solids in centrate and total solids in sludge cake from batch centrifugation of vegetable cannery activated sludge.

Table 1. COMPARISON OF POLYMERS AT 40 mg/l TO AID IN CLARIFICATION OF VEGETABLE ACTIVATED SLUDGE SUSPENSIONS[a] BY CENTRIFUGATION[b]

Polymer, 40 mg/l	Turbidity FTU	Suspended solids in centrate	
		mg/l	% capture
None	600	1,804	87.5
Chitosan	45	171	98.8
WT-2680	210	857	94.4
WT-2660	45	217	98.7
WT-2640	290	1,256	93.0
Natron 86	25	128	99.0
Floc 534	125	791	94.0
Betz 1190	69	396	97.1
Betz 1160	67	411	97.1
Atlasep 105c	48	233	98.8
Floc 535	66	346	97.8
WT-3000	720	2,743	83.1

[a] Sludge feed: 8.1 to 8.7 l/min, suspended solids, 12,500 to 19,600 mg/l.

[b] Centrifuge speed: 3,200 rpm (1,740 G's).

Table 2. COMPARISON OF CHITOSAN, WT-2660, AND NATRON 86 AT DIFFERENT CONCENTRATIONS TO AID IN CLARIFICATION OF VEGETABLE ACTIVATED SLUDGE SUSPENSIONS BY CENTRIFUGATION

Experiment Number	Polymer	Concentration of polymer, mg/l					
		10		20		40	
		Suspended solids in centrate					
		mg/l	% cap.	mg/l	% cap.	mg/l	% cap.
I	Sludge feed rate, 8.6 l/min[a]						
	Chitosan	321	97.9	248	98.4	177	98.5
	WT-2660	1,255	92.5	697	96.1	285	97.4
	Natron 86	1,047	93.7	565	96.5	177	98.2
II	Sludge feed rate, 13.3 to 14 l/min[b]						
	Chitosan	204	97.8	150	97.1	92	98.8
	WT-2660	260	90.0	219	92.3	63	95.6
	Natron 86	267	93.9	182	97.4	72	97.5

[a] Suspended solids in sludge feed ranged from 10,000 to 18,000 mg/l.

[b] Suspended solids in sludge feed ranged from 1,500 to 9,200 mg/l.

Seattle, Washington.[15] Marine Commodities International, Inc., is constructing a plant in Brownesville, Texas for production of chitin, chitosan, and protein by-products.[16]

Composition of Coagulated By-Products

The coagulated by-products derived from treatment of food processing wastes generally contain significant amounts of protein, and in some cases, fat. Table 3 shows the proximate analysis (dry weight basis) of three samples of coagulated brewery sludge. The content of fat, fiber, and ash averaged 2.0, 6.6, and 16.1 percent, respectively. Crude protein content, determined by Kjeldahl analysis (N x 6.25) was 50.8 percent. However, the Kjeldahl values include nitrogen in cell wall structures, such as amino sugars and D-amino acids, nitrogen in nucleic acids, as well as nitrogen in intracellular proteins. Based on the total amino acids found in acid hydrolysates of the coagulated brewery sludge, the true protein content was 36.9 percent rather than 50.8 percent obtained by Kjeldahl analysis. The biuret method developed for microbial protein[10] such as found in activated sludge involves treating the biomass with boiling 3 N alkali for five minutes to extract most intracellular proteins. The protein content estimated by this biuret method was 40.7 percent compared to 36.9 percent by amino acid analysis and 50.8 percent by Kjeldahl analysis. This biuret method for protein is much simpler and less expensive for routine analysis than obtaining a complete amino acid analysis. We have used this method effectively for "single cell protein" produced from meat packing wastes[17] and are currently using it to estimate protein on a wide range of waste products. In activated sludge, which is a mixture of microorganisms, analysis of intracellular protein is the best indicator of the protein nutritionally available for animals. Work with pure cultures of microorganisms for production of "single cell protein" has shown that the nutritionally valuable proteins are those contained inside the cell walls of the microorganisms. Nitrogen in cell walls and nucleic acids is of little or no nutritional value to non-ruminant animals.[18,19]

The analysis of coagulated activated sludge from treatment of vegetable canning wastes is shown in Table 4. Fat and ash were 0.7 percent and 20.2 percent, respectively. The high ash content of the sludge is believed to be due in part to adsorption of clay and minerals from wastewaters produced by washing of leafy greens and root crops in the plant. The crude protein content was 33.6 percent by Kjeldahl analysis. Based upon the amino acid content, the protein content was 28.5 percent while the biuret method estimated intracellular protein to be 31.4 percent of the dry weight.

Table 3. PROXIMATE ANALYSIS OF COAGULATED BREWERY SLUDGE[a]

Component	Content, %	
	Average[b]	Range
Fat	2.0	1.4-2.6
Fiber	6.6	6.2-7.1
Ash	16.1	14.0-20.1
Crude protein (N x 6.25	50.8[c]	49.7-52.0
Protein by amino acid analysis	36.9	36.5-37.2
Protein by biuret method	40.7	38.1-42.0

[a] Ratio of chitosan to suspended solids in sludge was 0.72 to 0.82%.

[b] Average of three samples.

[c] Includes approximately 0.06 g N in chitosan/100 g sludge which accounts of 0.7% of total N.

Table 4. PROXIMATE ANALYSIS OF COAGULATED VEGETABLE SLUDGE[a]

Component	Content, %	
	Average[b]	Range
Fat	0.7	0.2-1.2
Ash	20.2	15.9-24.5
Crude protein (N x 6.25)	33.6[c]	31.9-36.2
Protein by amino acid analysis	28.5[d]	27.4-30.3
Protein by biuret method	31.4	27.5-33.0

[a] Ratio of chitosan to suspended solids in sludge was 0.3 to 0.4%.

[b] Average of four samples.

[c] Includes approximately 0.027 g N in chitosan/100 g sludge which accounts of 0.5% of total N.

[d] Average of two samples.

Table 5 shows the proximate analysis of coagulated solids from egg breaking wastes. This material contained 4.9 percent ash and 39.4 percent fat. The crude protein content was 45.6 percent compared to 41.8 percent protein by amino acid analysis.[5]

The essential amino acids in the coagulated by-products from egg breaking wastes, vegetable cannery sludge, and brewery sludge are compared in Table 6 to the FAO pattern of essential amino acids and to meat and milk.[20] The composition of Brewer's Single Cell Protein (BSCP) produced by drying of activated sludge at the Adolph Coors Co., Golden, Colorado, is also shown.[21] The coagulated by-products contained adequate amounts of all of the essential amino acids with the exception of the sulfur-containing amino acids cystine and methionine. The acid hydrolysis method used in this study destroyed cystine, tryptophan, and a portion of the methionine. Hence, values for two of these amino acids were, with the exception of tryptophan in brewery sludge, unavailable. The amino acid content of Coor's sludge[21] and the brewery sludge analyzed in this study are similar. The Coor's sludge product contained 8.0 percent fat, compared to 0.7 percent in this study, because it was dried with the Carver-Greenfield process which uses a fluidized bed of oil to suspend the product.[22] Dry solids are separated from the oil by centrifugation, but some of the oil remains in the product.

Activated sludge produced from citrus wastes has been evaluated by Damron et al. as a poultry feed ingredient.[23] This citrus sludge contained 38.6 percent protein which compares closely with an average of 36.9 percent based on amino acid analyses of brewery sludge samples in this study. Feeding citrus sludge to hens improved yolk color in eggs. This enhancement may be due to citrus pulp solids which were possibly recovered and dried along with the activated sludge solids.

Physiological Effects of Chitosan on Rats

In order for coagulated by-products to be recycled into animal feeds, it will be necessary to obtain approval from the Food and Drug Administration for incorporation of small amounts of the coagulating agent into feeds.[24] In our preliminary feeding trial with rats, the animals fed all but the highest level (5 percent) of chitosan grew as well as those fed the control diet without added chitosan as indicated by final weight of animals and feed efficiency (Table 7). The animals were healthy and vigorous and displayed no overt symptons of physiological distress due to consumption of the chitosan. The normal values obtained for hemoglobin and hematocrit levels in the blood (Table 8) are further evidence of the general well-being of the animals. The most noticeable effect of additions of the polymer to the the diets was a reduction in the final weight of the animals with the highest level of chitosan. This might be due to palatability factors such as the size

Table 5. PROXIMATE ANALYSIS OF COAGULATED SOLIDS FROM EGG BREAKING WASTES[a]

Component	Content, %	
	Average[b]	Range
Fat	39.4	35.1-45.3
Ash	4.9	2.9-8.8
Crude protein (N x 6.25	45.6	42.2-49.4
Protein by amino acid analysis	41.8	37.1-47.3

[a] Table 7 from Bough.[5]

[b] Average of five samples.

Table 6. A COMPARISON OF ESSENTIAL AMINO ACIDS IN BY-PRODUCTS RECOVERED FROM FOOD PROCESSING AND TREATMENT WASTES BY COAGULATION WITH CHITOSAN

Essential amino acids	g amino acid/100 g total amino acids in acid hydrolysate						
	Coagulated by-product			Reference protein			
	Egg breaking waste[a]	Vegetable act. sludge[b]	Brewery act. sludge[c]	Essential FAO pattern[d]	Milk[d]	Meat[d]	Coor's BSCP[e]
Threonine	4.8	5.3	5.2	2.8	4.57	4.6	6.6
Valine	6.1	6.4	7.0	4.2	5.43	3.3	8.3
Cystine	-[f]	-[f]	-[f]	2.0			
Methionine	2.6	1.6	3.5	2.2	4.0	4.2	3.5
Isoleucine	5.5	4.4	5.0	4.2	4.28	3.3	6.0
Leucine	8.8	7.5	8.2	4.8	16.28	12.5	9.5
Phenylalanine	5.7	6.9	5.3	2.8	5.71	4.6	5.8
Tryptophan	-[f]	-[f]	1.9[g]	1.4	1.71	1.3	
Lysine	5.9	5.4	4.0	4.2	7.43	8.3	5.6

[a] Average of five samples.

[b] Average of two samples.

[c] Average of three samples.

[d] R. Dabbah.[20]

[e] Brewer's single cell protein.[21]

[f] Destroyed by acid hydrolysis.

[g] Assayed by microbiological method.[12]

Table 7. PRELIMINARY RESULTS ON EFFECTS OF CHITOSAN IN RAT DIETS ON FEED INTAKE, EFFICIENCY, AND BODY WEIGHT[a]

Chitosan in diet, %	Chitosan intake, g/kg body wt./day	Avg. total intake, g	Feed efficiency[b]	Avg. final wt. of animal, g
0	0.0	757^{1}[c]	0.336^{1}	325.8^{1}
0.5	0.44	776^{1}	0.325^{1}	323.4^{1}
1.0	0.91	700^{1}	0.318^{1}	$293.8^{1,2}$
2.0	1.82	638^{1}	0.320^{1}	$294.6^{1,2}$
5.0	4.98	679^{1}	0.288^{2}	267.8^{2}

[a] Five rats per died fed for 5 weeks on a standard casein diet.

[b] Feed efficiency is g of weight gained per gm of feed consumed.

[c] Values followed by the same superscript number are not significantly different at the 1% level of confidence.

Table 8. PRELIMINARY STUDY ON PHYSIOLOGICAL EFFECTS OF CHITOSAN IN RATE DIETS ON LIVER WEIGHT, HEMOGLOBIN, AND HEMATOCRIT[a]

Chitosan in diet, %	Liver		Hemoglobin, g/100 ml	Hematocrit, %
	Wt., g	% body wt.		
0	14.69^{1}[b]	4.50^{1}	14.76^{1}	50.6^{1}
0.5	14.36^{1}	4.44^{1}	15.38^{1}	52.4^{1}
1.0	12.62^{1,2}	4.29^{1,2}	15.42^{1}	53.3^{1}
2.0	11.77^{2}	3.99^{2}	15.45^{1}	52.3^{1}
5.0	11.30^{2}	4.22^{1,2}	15.39^{1}	52.9^{1}

[a] Five rats per treatment fed for 5 weeks on standard casein diets.

[b] Values followed by the same superscript number are not significantly different at the 1% level of confidence.

and hardness of chitosan particles. Chitosan was added to the diets as solids particles ground to pass a 20 mesh screen. The animals would try to pick out these particles. In actual use as a coagulating agent, chitosan will be dissolved in dilute acetic acid for application to food wastes. Molecules of chitosan which are adsorbed and incorporated into particles of coagulated solids will be evenly distributed along with proteins and fats. Thus, the animals will not notice any physical discomfort due to chitosan particles. The reduction of feed intake probably contributed to the reduced weight of the animals fed the diet containing 5 percent chitosan, but the rate of feed conversion by these animals was also lower than that of controls. Liver weight was reduced in rats fed diets containing 2 percent or 5 percent chitosan. In the latter group of animals, the decreased liver size was associated with a general depression of growth so that liver as a percent of the total body weight was not different from the controls. In animals fed 2 percent of the polymer in the diet, liver as a percent of the body weight was lower than the controls. There is no obvious explanation for this difference.

Arai et al. found that chitosan fed to mice caused no harmful effects up to 18 grams per kilograms body weight per day. Above this amount, toxic effects were observed.[25] Our experiment with rats suggests that levels up to 2 percent of chitosan can be fed without significantly affecting the growth or health of the animal. A concentration of 2 percent chitosan in the diet is greater than levels anticipated in commercial use. Coagulated vegetable sludge and brewery sludge in this study contained 0.3 to 0.4 percent and 0.72 to 0.82 percent chitosan, respectively. If 10 to 20 percent of such a coagulated by-product is incorporated in an animal feed as one of the protein sources, then the concentration of chitosan in the feed would be less than 0.2 percent in even the highest case. No adverse effects due to 0.5 percent chitosan in the diet have been observed in our experiments thus far. Significant weight reduction was observed at 5 percent chitosan in the diet, but this is probably 10 to 25 times the concentrations expected from use of coagulated by-products in animal feeds. These results on the physiological effects of chitosan are considered to be preliminary. This experiment is being repeated with more animals and for a longer period of time.

Our data on the use of chitosan for recovery of coagulated by-products from food processing wastes and treatment systems have been summarized and submitted to the Non-Ruminant Branch of FDA as a preliminary proposal for approval of chitosan as a coagulating agent to be incorporated into animal feeds as an ingredient of coagulated by-products.

The estimated supply of activated sludge from the food industry is quite large. Garner et al. of the USDA estimated the total production of BOD from food and kindred products to be 4,300 million pounds annually.[26] Assuming 0.3 pounds dry activated sludge will be wasted or utilized per pound of BOD, then 1,290 million pounds of sludge could be produced from food and kindred wastes. However, the National Industrial Pollution Control Council reports 62 percent of cannery waste and 80 percent of dairy products waste are treated in municipal facilities.[27] So, if we assume that 25 percent of the total BOD load from the food industry is treated in private facilities, separate from domestic wastes so that the activated sludge could be safely utilized as feed ingredients, the supply of dry sludge would be 322 million pounds (25 percent x 1,290 million pounds).

McWhorter has reported the total BOD load from United States breweries to be 338 million pounds.[28] He estimates the potential supply of brewery sludge to be 169 million dry pounds. While some of this supply is now being handled in municipal plants, the recent trend, he observes, is for breweries to be large in size, located in rural areas, and to construct and operate their own waste treatment facilities.

The annual supply of chitosan which could be produced in the United States has been estimated by Peniston to be 10 million pounds.[29] Assuming a ratio of 1 percent chitosan to sludge solids, the amount of chitosan required to condition 322 million pounds of sludge from food wastes and 167 million pounds of brewery sludge would be approximately 5 million pounds or 50 percent of the annual supply. Thus, it is possible that chitosan, which is itself derived from shellfish wastes, may serve a unique function in the recovery of coagulated by-products from food processing and treatment wastes. Recovery of activated sludge appears to be one of the most effective uses of chitosan.

ACKNOWLEDGEMENTS

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Chitosan was obtained from Food, Chemical, and Research Laboratories, Inc., Seattle, Washington. Other polymers (identified by prefix) were obtained from the following sources: "Betz", Betz Laboratories; "Atlasep", Atlas Chemical Corporation; "WT", Calgon Corporation; "Nation", National Starch and Chemical Corporation; and "Floc", DuBois Chemicals.

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DOUBLE-DIP CAUSTIC PEELING OF POTATOES

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INTRODUCTION

In order to improve the overall efficiency of lye peeling, we have examined the effects of different procedures of lye application. Earlier work,[1,2] which resulted in a reduction of lye requirements for peeling, introduced some form of heat, such as high pressure steam or infrared heat to make a relatively small amount of absorbed caustic more effective. However, with the recent increases in energy costs, and perhaps limited availability of energy, a mere substituion of heat for lye may not improve overall efficiency. Our objective in the work described here was to develop procedures for applying caustic to potatoes, and other fruits and vegetables, so that a given amount of absorbed caustic would be more effective for peeling, without requiring additional heat input.

In the initial development of the dry caustic peeling process,[2] we obtained the curves shown in Figures 1 and 2. Figure 1 depicts caustic uptake as a function of immersion time in the lye solution for several lye concentrations. The curves indicate a lag period followed by a rapid, almost linear, rate of caustic uptake. Figure 2 shows peel loss as a function of the hold time between lye immersion and infrared application in the standard dry caustic peeling process. Peel loss continues to increase with hold time for holding periods of at least 15 minutes.

From these two figures we intuitively reasoned that caustic first modifies the suberized layer of the potato, making it more penetrable for caustic diffusion, and subsequently rapidly attacks the underlying

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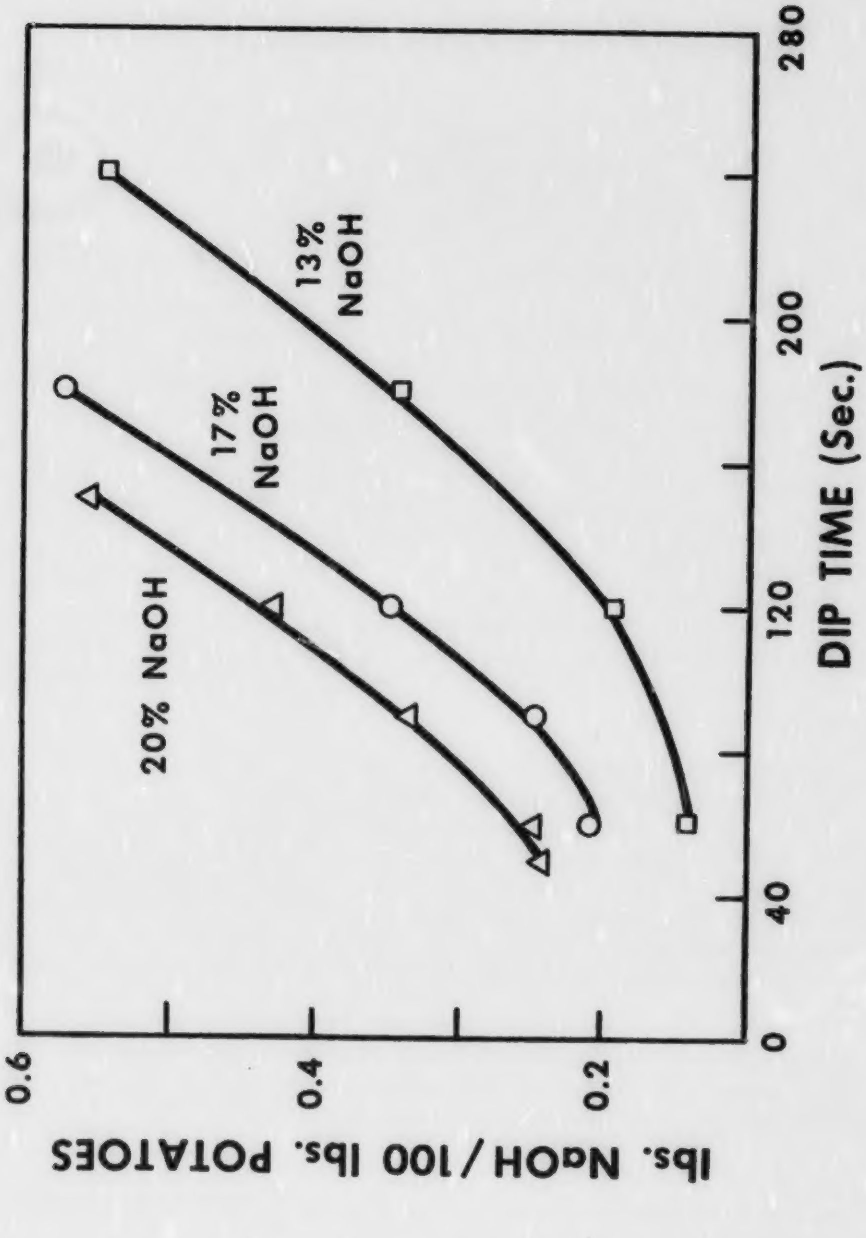

Figure 1. NaOH absorbed by US No. 1 Russett potatoes in 170°F lye.

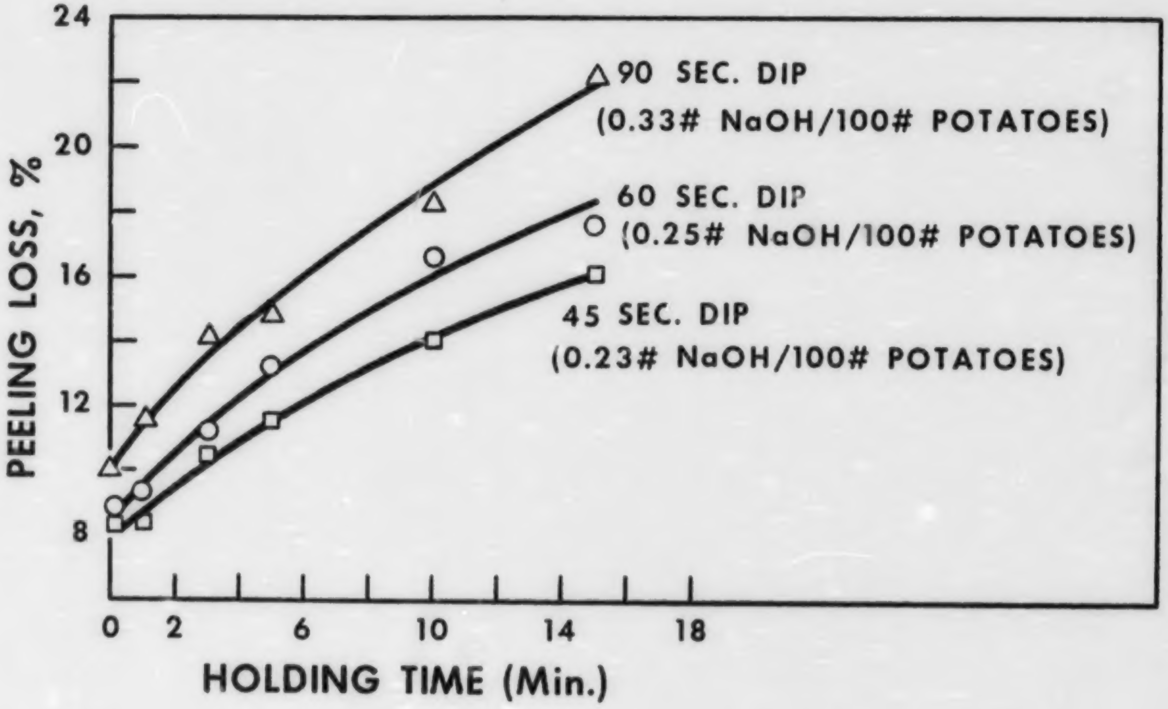

Figure 2. Effect of holding time at ambient temperature.

potato flesh, resulting in the rapid caustic uptake. It was also evident that absorbed caustic continued to attack the potato tissue even though the potatoes were held at ambient temperature.

We, therefore, concluded that a peeling process would be most efficient in the use of caustic when the caustic applications are staged, i.e., one to modify the outer suberized layer and one to attack the underlying tissue, with holding periods following each application to maximize the effects of the absorbed caustic. Such a process is diagrammed in Figure 3.

METHODS

Individual potatoes were washed, weighed, and impaled on stainless steel spits. Caustic solutions were made to given concentrations using analytical reagent grade sodium hydroxide pellets (minimum NaOH assay 98 percent). Approximately seven pounds of a given solution were placed in a stainless steel pot which was heated by an electric hot plate. Calibrated dial thermometers were used to indicate the solution temperature. When the desired immersion temperature was reached, the impaled potato was placed in the solution and the spit was rotated to thoroughly stir the solution. The temperature was controlled manually. Following immersion for the specified time, the potato was held on the spit and exposed to the ambient conditions of the laboratory, where the temperature was usually 70 to 75 degrees F. Immersion and holding times were measured with a stop-clock.

Following a given series of immersions and holding periods, the potatoes were either peeled or subjected to infrared heat. When infrared heat was used, the impaled potato was rotated under a gas-fired infrared burner with the nearest surface of the potato two inches from the radiating ceramic mantle. The irradiating surface temperature was about 1,600 degrees F.

Peeling was accomplished by hand brushing under a small flow of water or by use of a small mechanical laboratory dry peeler[2] utilizing rotating rubber-tipped rolls. When the mechanical peeler was used, the potatoes were subsequently hand brushed under a small flow of water to remove a small amount of remaining loose peel material.

The peeled potatoes were weighed to determine the amount of material removed as peel, and a visual inspection was made to ascertain the degree of "heat ring" formation and the overall peeling quality.

Lye uptake was measured by a previously described technique[2] in which about five to ten pounds of caustic treated potatoes are placed in

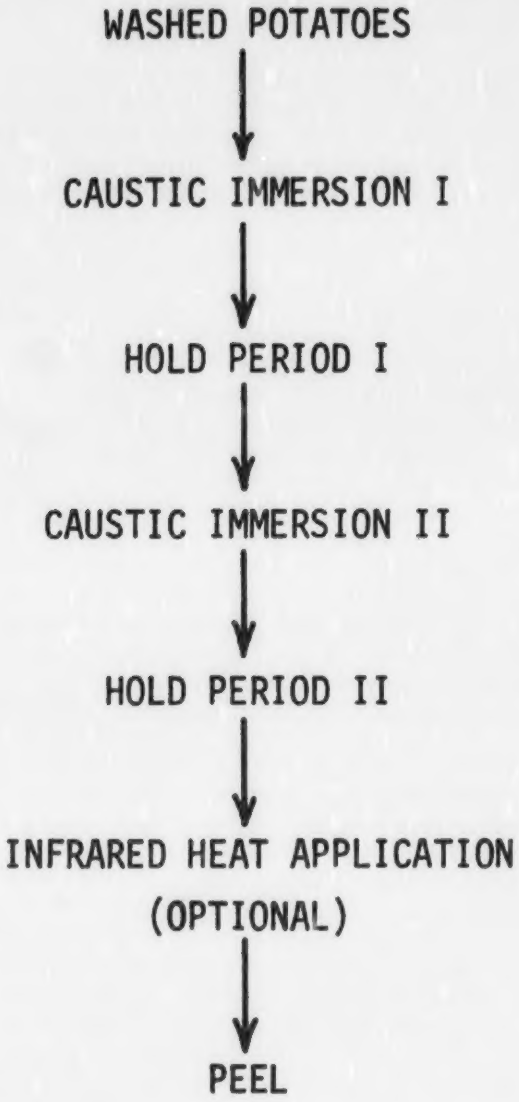
WASHED POTATOES
CAUSTIC IMMERSION I
HOLD PERIOD I
CAUSTIC IMMERSION II
HOLD PERIOD II
INFRARED HEAT APPLICATION
(OPTIONAL)
PEEL

Figure 3. Flow diagram of double-dip peeling process.

a known volume of standard dilute acid. After the caustic in the potatoes has had time to react with the acid (about 15 minutes), an aliquot of the acid solutions is taken. Back titration with sodium hydroxide then determines the quantity of acid neutralized by the caustic on the potatoes. Thus, the quantity of caustic on a given weight of potatoes is determined.

Because potatoes, even of the same variety, are known to vary widely in their peeling characteristics, due to variations in culture and storage, each series of tests was made with potatoes from the same lot which were hand selected to provide uniformity of size, shape, and peel characteristics. All results reported here were obtained from Russet-Burbank potatoes.

RESULTS

Figure 4 shows the effect of the hold period between the two caustic applications on the peel loss for several combinations of caustic treatments. The upper curve respresents 8 percent NaOH at 88 degrees C for 30 seconds in both the first and second dip, while the bottom curve represents a 5 percent NaOH solution at 88 degrees C for both 30-second dips. A zero hold time thus corresponds to one continuous dip of 60 seconds. The middle curve represents an 8 percent NaOH solution at 88 degrees for 30 seconds in the first dip and a 5 percent NaOH solution at 88 degrees C for 30 seconds in the second dip. To avoid dilution of the first dip caustic by the lower second dip caustic, a minimum hold time of five minutes was used. All curves shown in Figure 4 were obtained with a one-minute infrared heat application.

Figure 5 depicts peel loss as a function of infrared exposure time for two caustic treatments. The upper curve represents a double dip treatment---45 seconds immersion in 10 percent NaOH at 88 degrees C, a 15 minute ambient hold, a 45 second immersion in 5 percent NaOH at 88 degrees C, and a three minute ambient hold. The lower curve represents a single 60-second immersion in 10 percent NaOH at 90 degrees C followed by a three-minute ambient hold, which is typical of the caustic treatment used in standard infrared dry caustic peeling. Caustic uptake for the double-dip treatment was 0.066 pounds NaOH per 100 pounds potatoes, and the uptake for the single dip was 0.088 pounds NaOH per 100 pounds potatoes.

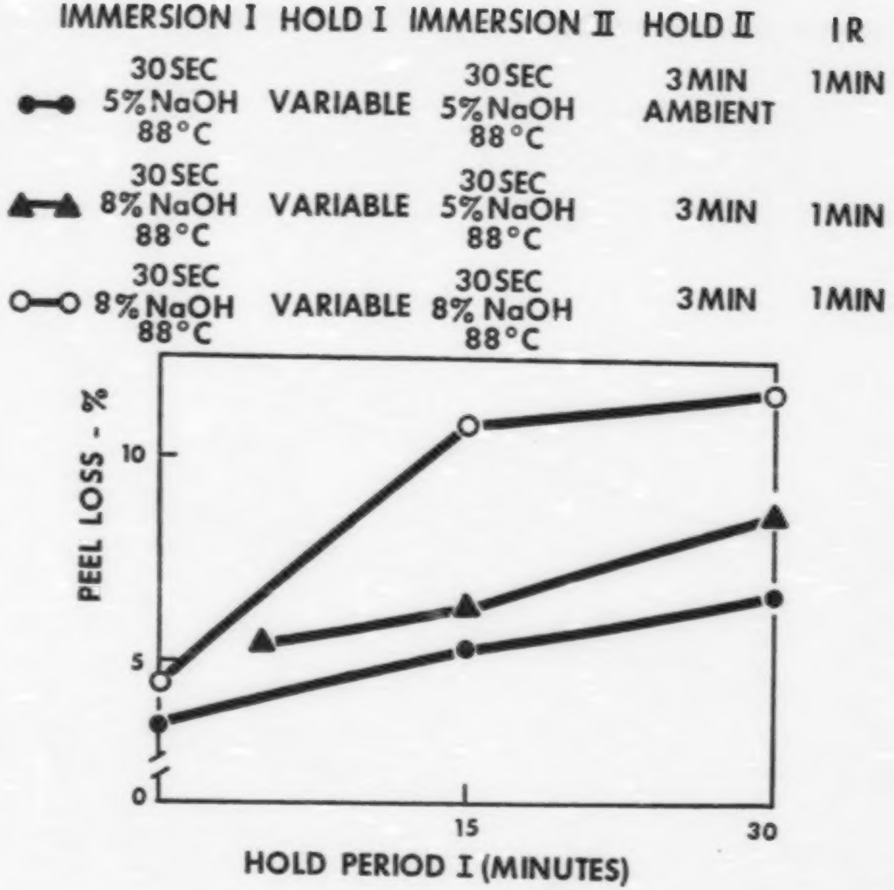

Figure 4. Peel loss versus hold period between caustic immerisions.

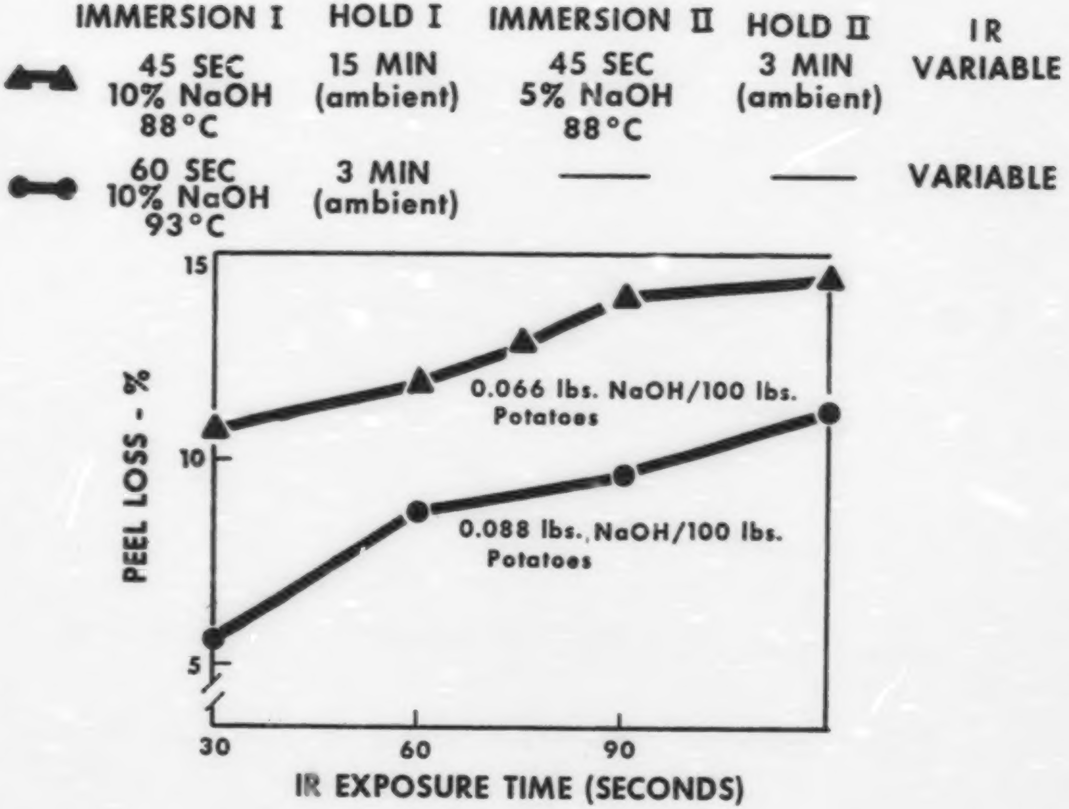

Figure 5. Peel loss versus infrared exposure time for double-dip and standard lye applications.

DISCUSSION

From Figures 4 and 5 it is evident that the double-dip treatment has a substantial effect on peel loss. Figure 4 shows that during the hold period between the two dips, the caustic absorbed in the first dip is in fact modifying the peel surface so that the second dip becomes more effective in removing tissue. For the lower curves, where only 5 percent NaOH is used in the second dip, peel loss increases nearly linearly with hold time for a hold period up to at least 30 minutes. When 8 percent NaOH is used in both dips, as in the upper curve of Figure 4, the effect of the hold time diminishes after about 15 minutes.

The improved efficiency of the caustic in a "double-dip" treatment versus a standard single dip treatment is evident from Figure 5. Even though the total caustic uptake is less for the double-dip system, the peel removed is greater than for the single dip regardless of the amount of infrared heat applied. In fact, the peel loss without infrared heat in the double dip treatment corresponds to the peel removed in a single dip treatment followed by 60 to 90 seconds of infrared irradiation. Also, the effect of infrared heat levels out at about 60 seconds of irradiation for the double-dip system, but for the single dip system the peel loss continues to increase for up to at least 90 seconds of infrared irradiation.

Of course, the object of a good peeling process is not to obtain high peel losses, per se. The results given in Figures 4 and 5 only show the improved efficiency of a given quantity of lye when the double-dip system is used. Good peeling occurs when, for a given amount of peel loss, all eyes and minor surface defects are removed without excessive development of surface "heat ring". Figure 6 is a photograph of potatoes peeled at various stages of the double-dip method. The final peeled potato is free of all eye tissue and surface defects and essentially no heat ring has developed.

CONCLUSIONS

Our results show that the double-dip caustic peeling system can effectively increase peeling efficiency without the use of additional energy input. In fact, the caustic efficiency for the double-dip system appears to be equivalent to the caustic efficiency of the single dip system combined to 60 to 90 seconds of infrared heat. Thus, the double-dip system offers a means of avoiding the high energy consumption of the infrared system. Moreover, a "rule-of-thumb" in the potato industry is that about one pound of caustic is required to peel 100 pounds of potatoes in standard lye peelers without infrared. Our data show that caustic usage with the double-dip system is 10 percent or less of this

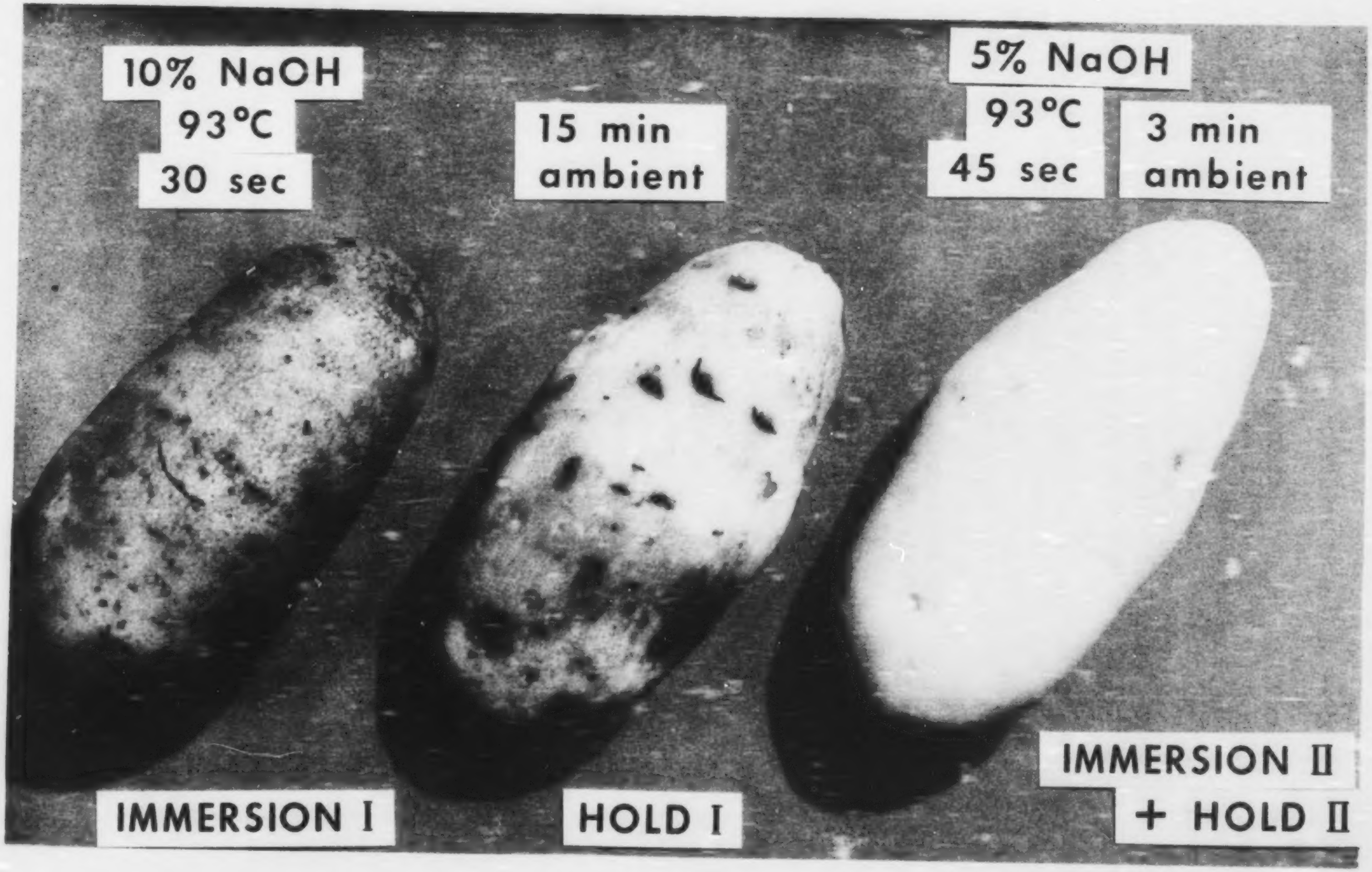
10% NaOH
93°C
30 sec
15 min
ambient
5% NaOH
93°C
45 sec
3 min
ambient
IMMERSION I
HOLD I
IMMERSION II
+ HOLD II

Figure 6. Photograph of potatoes peeled at various stages of double-dip process (no infrared heat).

amount. Even if commercial installations of the double-dip system require two or three times as much caustic as our idealized laboratory system, substantial caustic savings may be realized. Because lye is made through the energy intensive process of electrolysis and evaporative concentration, reductions in caustic usage indirectly reduce energy requirements for the system as a whole.

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EGG BREAKING AND PROCESSING WASTES CONTROL AND TREATMENT

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INTRODUCTION

Control of wastewaters from many food processing facilities are complicated because of their location and the highly contaminated wastes which they produce. For many types of foods it is necessary to locate the processing facilities near the source of the raw material. This often means that the facility will be located in rural areas where the pollution control facilities may have difficulty handling complex food wastes. Due to lower tax bases and less organized government structures in small communities, the organizational structures required to respond to pollution control planning may not be effective. The egg processing industry is an example of a food processor that is often located in rural areas and may have diffucult wastewater control problems.

The new federal pollution control laws require that all industries, including food processors, assume responsibility of achieving a high degree of control over their wastes in the near future. This responsibility can be met by using a number of alternatives, including efficient treatment and direct discharge of the purified effluent,

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discharge elimination using land disposal of the wastes, no treatment and discharge to a municipal system, or treatment to a level comparable to domestic sewage and discharge to a municipal treatment facility. The U.S. Environmental Protection Agency (EPA) has specified the discharge requirement that must be met by many industries for two future time periods. Wastewater control technology equivalent to using the "best practicable control technology currently available (BPT)" is to be in use by July 1, 1977; while the pollution control equivalent to the "best demonstrated technology economically achievable (BAT)" must be in use by July 1, 1983. Preliminary discussion effluent guidelines have recently been issued for the egg breaking industry.

In order for the many food processing industries to meet the allowable discharge quantities, it is often necessary to reduce the effluent BOD concentration from several thousand milligrams per liter to 20 to 40 milligrams per liter. This level of control is difficult and expensive to achieve by wastewater treatment processes. The obvious alternative to complete "end of pipe" treatment is to prevent the pollutant loss through in-plant control. Successful in-plant control of wastes can result in capture of valuable food products which can be translated into a method of minimizing the costs of pollution abatement. A two-phased approach to determine the maximum waste that could be conserved by in-plant control followed by treatment of the resulting wastewater was the approach of this study.

OBJECTIVES

This study of the egg breaking industry is divided into three sections: a review of the characteristics of the industry as a whole, characterization and control of wastes in five egg breaking plants, and investigations into the treatability of wastewaters from egg breaking facilities. The data is applicable to a wide range of plant capacities, since detailed industry analyses included the largest and most complex egg breaking facility, even though the majority of information was developed for facilities with one, two or three egg breaking machines. Although the waste problems associated with processing eggs to bring them to the shell egg market were not evaluated, the first steps in shell egg handling are similar to those used in egg breaking plants. Therefore, portions of the data developed in this study could be used to approximate the waste problems of this division of the egg processing industry. The solid waste problems generated by egg breaking facilities were defined but the disposal alternatives were not developed in this study.

It was the general goal of this study to provide an overview of the industry which would include practical and inexpensive in-plant waste management methods and determine the problems of treatment of the wastes. The specific objectives of this study were to:

1. Describe the characteristics of the industry; past, present and future.
2. Characterize the wastewaters generated in specific egg breaking facilities representing small, medium and large production capacities.
3. Develop in-plant waste management techniques to minimize the generation of waste material.
4. Conduct treatability tests of actual egg breaking wastewaters to determine the feasibility of reduction of pollutants.
5. Use the treatability results to suggest least cost and low energy consuming processes for treatment of wastewaters to various levels of contamination.

For further details see reference 1.

THE EGG BREAKING INDUSTRY

The number of egg breaking plants and the growth of the industry is summarized in Figure 1. The largest number of facilities was 477 in 1949 reflecting the influence of the Second World War. Except for the peak during the war years, this industry has grown at a linear rate of about 12 million pounds per year of increased production capacity. However, use of liquid egg products in quick food preparation and development of new products could have a significant effect on the future growth rate of this industry.

Production Rate Variability

In considering pollution control in this industry, one of the most important characteristics is the high variability of production rate. In its early development it was essentially a scavenger industry using surplus eggs at times of the year when shell production was depressed. Although the industry presently competes for good quality eggs throughout most of the year or imports the needed amounts, it is still highly susceptible to availability of supplies. The data shown in Figure 2 illustrates this variability in the United States over a three-year period and Figure 3 shows this pattern for one of the larger facilities sampled in this study. The whole industry faces shortages of

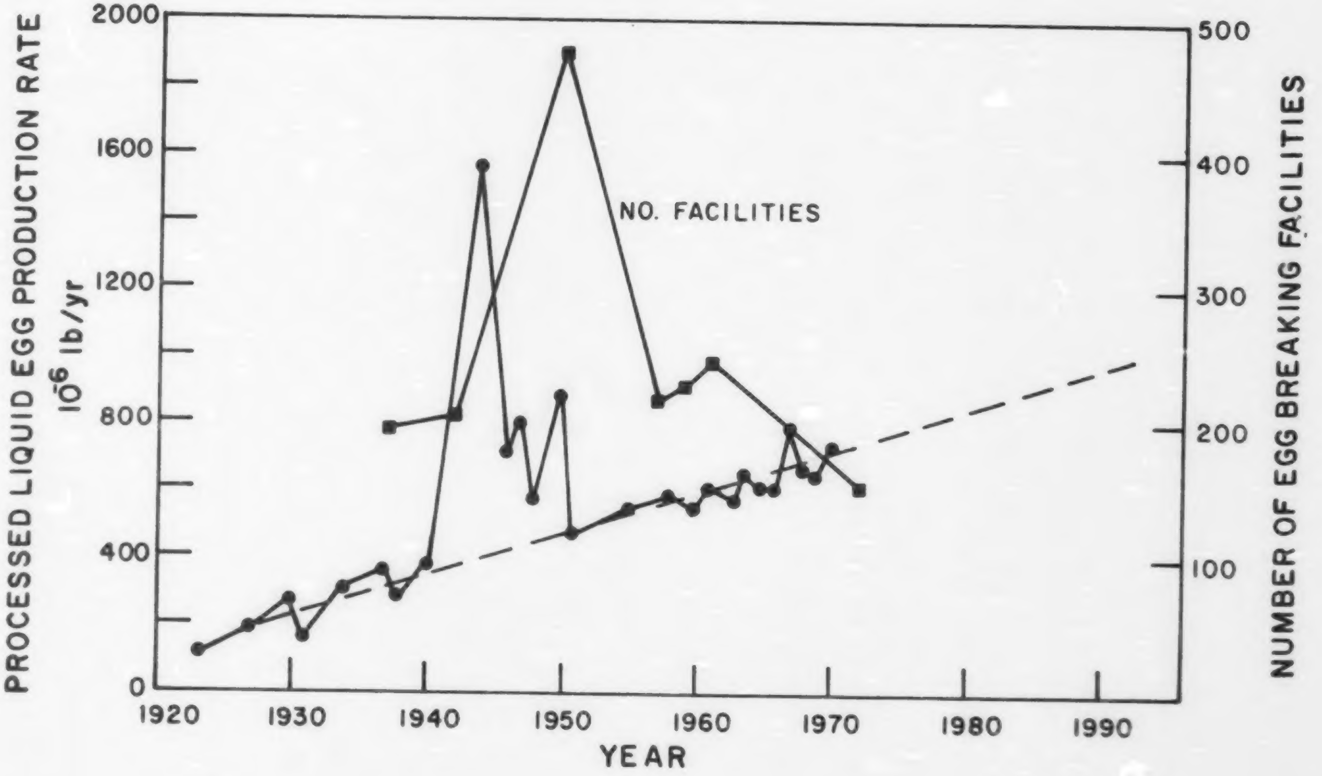

Figure 1. Annual US production of liquid egg products (dried, frozen and those used for immediate consumption) and number of plants under USDA inspection.

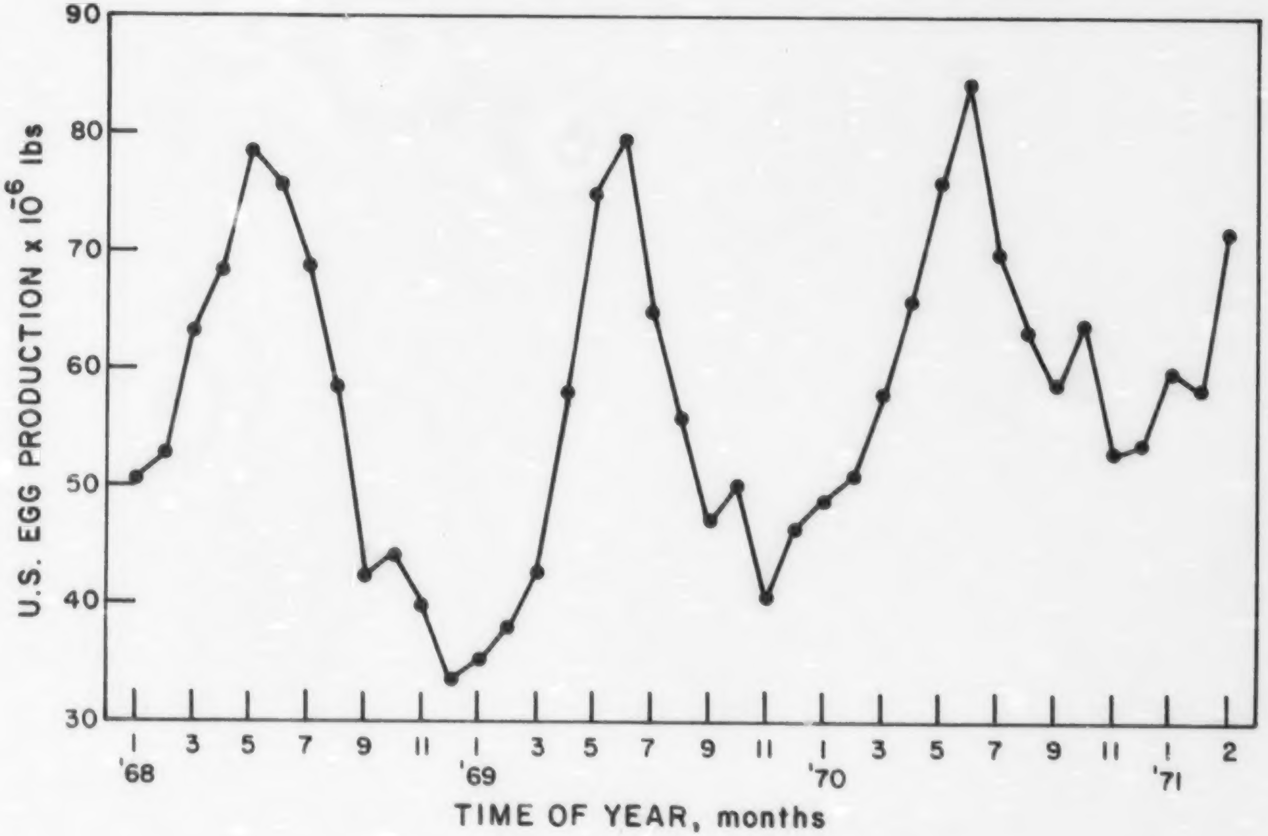

Figure 2. Monthly variations in US egg product production.

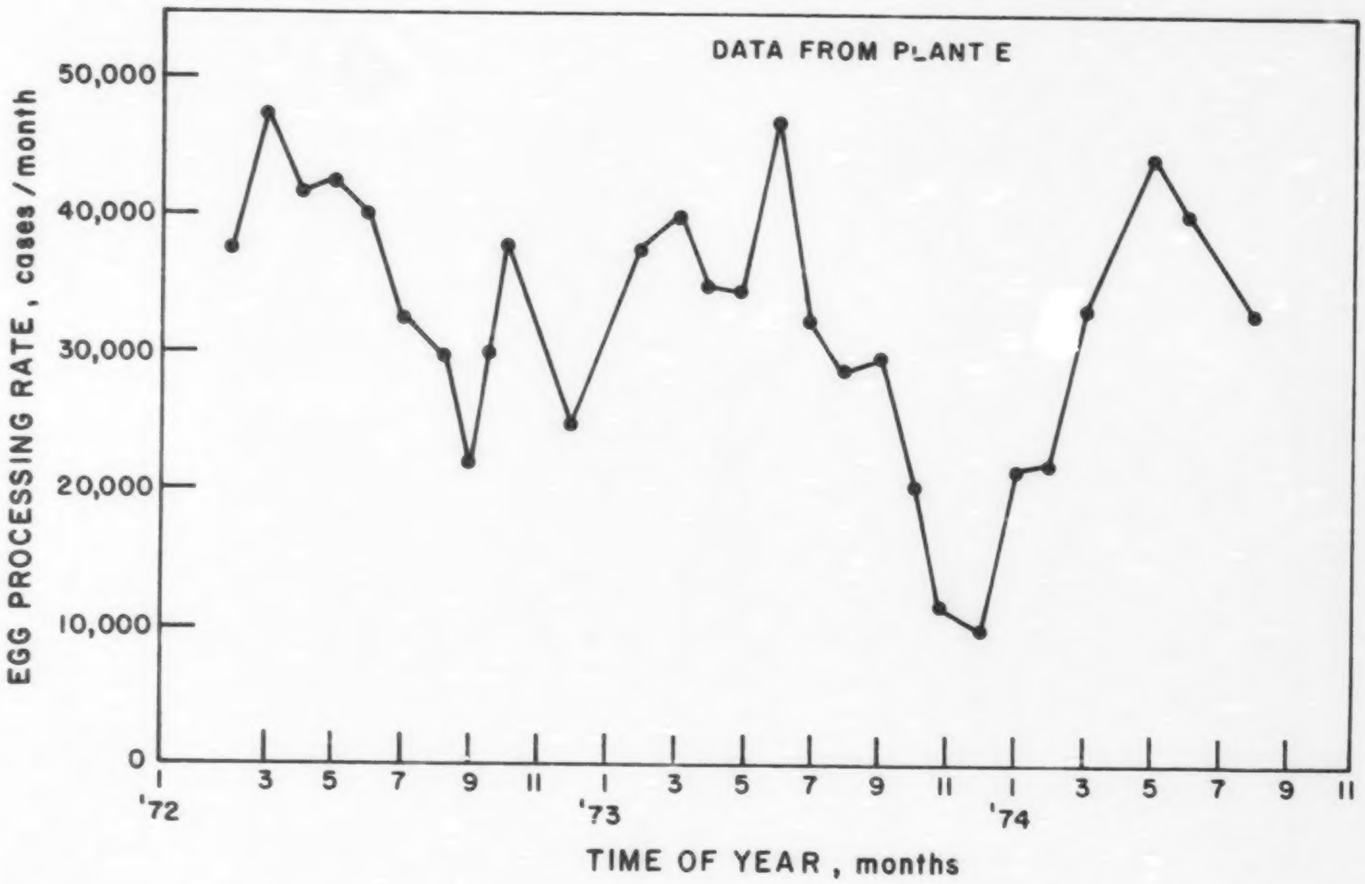

Figure 3. Monthly processing rate of eggs at Plant E.

raw material during the winter months of November and December and usually experiences a maximum production in the late spring and early summer. A wastewater treatment facility must be designed to handle peak loads during the period April through June, and be capable of effecient operation at only half the waste load during the period November through January.

The egg industry is, financially, the most important of the various poultry enterprises. In 1973 marketing of eggs accounted for 50 percent of the total $6.5 billion gross national income associated with all the poultry industry (eggs, broilers and turkeys).[2] Of the total eggs produced in the United States in 1972, 11 percent of the shell eggs were broken for use in producing egg products (liquid, frozen and dried eggs). The value of liquid eggs produced in the United States in 1965 was $195 million.[3]

Nearly half of all egg breaking facilities in the United States, or about 100 facilities, are presently plagued by some type of wastewater disposal problem.[4] Although the industry is relatively small it is distributed throughout the country with at least one plant in most states. However, very little was known about the waste characteristics of this industry and the capability of controlling the wastewaters.

Although the managers of several facilities estimated that their egg losses were between 6 percent and 10 percent of the processed egg, they did not know the impact of this loss on the pollution control facilities, the economic impact of this loss on their operation, or the potential for minimizing these losses.

WASTEWATER CHARACTERIZATION

Facility Location and Approach

Five facilities were sampled---three in New York State and one each in Georgia and Arkansas. The three New York plants were studied in great detail. A minimum of six days of 24-hour sample collections were used in the New York State facilities to enable reliable estimations of the waste loads before and after in-plant modifications. Two days of sampling were used to develop data for each of the two plants outside New York. Eighteen days of sampling provided information on waste characteristics for the most intensively examined facility (Plant A).

Project Approach

All plants were examined for total plant losses as well as unit process losses in order to identify in-house sources of waste. Methods to reduce wastes through in-plant modifications were suggested and implemented. Later, the sites were sampled again to measure the effects of the changes through repeated plant wastewater surveys.

Description of Processing Plants

A summary of the equipment used and type of product processing performed at the five plants surveyed is contained in Table 1. Independent of the plants' size, it was observed that the plants' layout and mode of operation were nearly identical. The flow diagram of an egg breaking operation in Figure 4 illustrates the various operations involved in preparing liquid, frozen or dried egg products from shell eggs. The first step in the operation is receiving the cartons of eggs from shell egg distributors. The eggs, which may have come from a distributor within a thousand-mile radius, are stored in a cool humid climate to maintain egg freshness and minimize evaporation of water from the egg.

Upon reaching the washer, eggs are manually loaded onto a conveyor belt. At this point the inspector removes any "leakers" which are broken shell eggs with contents exposed. Once a case of eggs has been loaded onto the washer, the empty cartons and filler flats are set aside to be returned to egg distributors, bailed for sale as scrap paper products or trucked to a sanitary landfill site. Most washers contain about a 50 gallon liquid volume which is continually recycled for a four hour period and then drained to the sewer system. Once the eggs have passed through the scrub brushes they are conveyed above a series of briliant lights for inspection in a candling operations. Inspectors remove "leakers", blood spot, and broken shells from eggs whose contents have been lost to the washer and eggs of poor interior quality. These inedible eggs are collected in segregated larger containers for pet food products.

Breakers in plants cooperating with this study operated at a rate of about 40 cases per hour which means that the employee at these machines examined eggs at four per second. The employee operating the breaking machine has the responsibility to (1) remove eggs containing blood spots, (2) remove spoiled eggs and cups into which they were broken, (3) manually break open any eggs which were not broken by the machine, (4) remove shell fragments which fall into the egg contents, and (5) trip the stainless steel cups to a full down position to be washed when they appear dirtly or when no egg was released into the cups. If the U.S. Department of Agriculture's (USDA) inspector notices

Table 1. SIZE AND TYPE OF EGG PROCESSING PLANTS SURVEYED

Plant identification	Number of egg washers	Number of egg breakers	Number of egg pasteurizers	Type of product processing
A	1	1	1	Frozen yolk, white and whole egg
B	2	3	1	Frozen yolk, white and whole egg
C	1	1	1	Frozen whole egg, liquid whole egg (bulk tank)
D	12	12	3	Frozen whole egg, dried, yolk and white and whole egg
E	8	8	2	Liquid, yolk, white and whole egg (bulk tank transport as liquid)

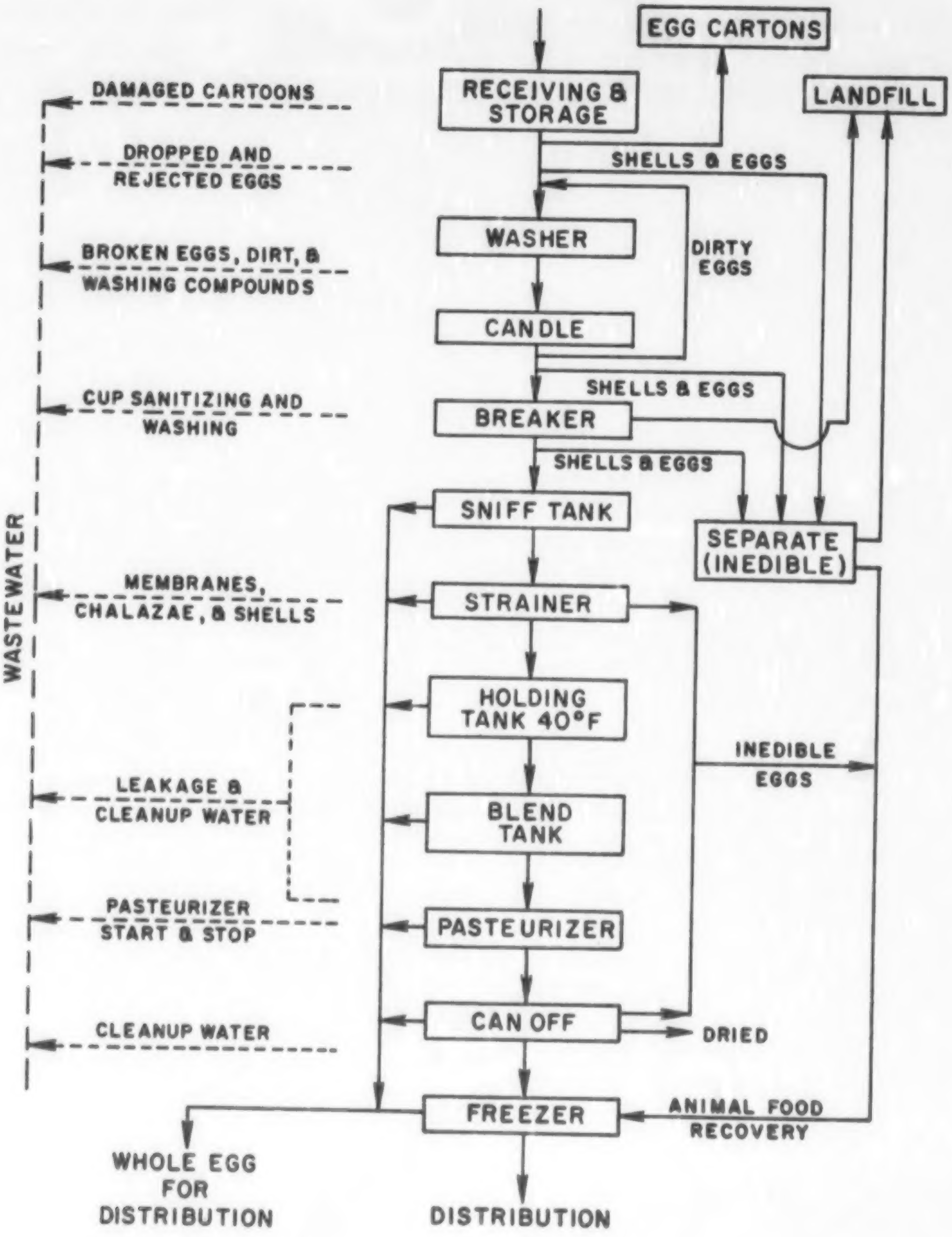
EGG CARTONS
DAMAGED CARTOONS
RECEIVING & STORAGE
LANDFILL
DROPPED AND REJECTED EGGS
SHELLS & EGGS
WASHER
DIRTY EGGS
BROKEN EGGS, DIRT, & WASHING COMPOUNDS
CANDLE
SHELLS & EGGS
CUP SANITIZING AND WASHING
BREAKER
SHELLS & EGGS
SNIFF TANK
SEPARATE (INEDIBLE)
WASTEWATER
MEMBRANES, CHALAZAE, & SHELLS
STRAINER
HOLDING TANK 40°F
INEDIBLE EGGS
LEAKAGE & CLEANUP WATER
BLEND TANK
PASTEURIZER START & STOP
PASTEURIZER
CLEANUP WATER
CAN OFF
DRIED
FREEZER
ANIMAL FOOD RECOVERY
WHOLE EGG FOR DISTRIBUTION
DISTRIBUTION

Figure 4. Flow diagram of product in egg breaking facilities.

dirty eggs on the breaker, he may stop the operation and order the complete machine cleaned. If the plant is not adequately equipped for pollution control, all the contents of the egg breaking machine at this point may be washed into the sewer instead of being saved for animal food or some other by-product.

Egg meats from the breaking machine collect in a small surge vat, and are pumped from the small vessel to a large sized sniff tank. The resident USDA inspectors require that this tank's drainage valve be closed until the sniff tank is full. After the sniff tank is physically examined by smell to be sure the produce does not possess obnoxious odors, sugar, salt and other condiments may be added to the product. The contents are drained through a coarse screen filter which retains shell fragments and the egg's chalazae.

The pasteurized product is cooled to 4.4 degrees C in a closed system of cooling plates from which it is pumped to a separate sanitary can-off room. Automatic filling machinery is used in this room to package egg meats in 13.6 kilogram (30 pound) cans, 1.9 liter (1/2 gallon) cartons or 4.5 kilogram (10 pound) plastic bags. Filled containers are prestacked on pallets to be placed in the freezer area.

The daily clean-up operations are some of the main sources of wastewater generation. Before work starts in the morning, the resident USDA inspector examines all machinery and its surroundings to be sure it is thoroughly cleaned and free of egg solids from the previous day's work. After four hours of operation, plant production is stopped because microbial buildup occurs and sanitary rules mandate that egg breaking areas be washed and sanitized. Frequently, substantial amounts of egg products that remain in the vats, filters and pipes are flushed onto the floor. After the machinery is cleansed it becomes necessary to wash down the floors to rinse away egg residuals, shells and cleaning liquids. Normal production continues for another four-hour period when production is stopped by another clean-up procedure. At the end of the work day there is a final complete and intensive washdown which is similar to the noontime clean-up except that the breakers are scoured and steam-cleaned manually.

Sampling Site Preparation

Frequently, food plants use municipal water for the majority of their water and simultaneously supply its refrigeration plant with private unmetered well water for cooling or wash-up water. Since detected sources of water can easily dilute wastewater to be sampled and thereby indicate an erroneously low wastewater strength, weirs were used to supplement the metered water use to measure total flows in order to monitor a plant's total discharge. After locating all pipelines which carried wastes and the floor drains (except employee restrooms), excavation was made and a weir box was fitted into position.

Wastewater samples collected at the outfall sampling stations were obtained by two methods. Grab samples were collected at half-hour intervals and proportioned into a composite sample according to flow volumes. An automatic sampler was also set to collect and combine nine equal sized samples per hour. Comparison of the values obtained from these two sampling techniques indicated that the more accurate flow composited samples were always less than the samples composited according to time only. In most cases the differences between values were less than 20 percent, even for the high or low values. The difference between the average concentrations was usually less than 10 percent. All values will be from the flow composited samples unless noted otherwise. All samples were stored on ice to minimize biological degradation, and chemical analyses were usually completed within 24 hours.

Example fluctuations of effluent wastewater and BOD_5 are shown in Figure 5 for one facility. The data shown in Table 2 summarizes the average wastewater characteristics before and after in-plant modifications were adopted for waste conservation. Methods of in-plant wastewater reduction will be discussed later. These data are averages of up to 19 days of 24-hour composite samples obtained from between 20 and 30 subsamples. The variation of the pollutants from Plants A, B and C are shown in Table 3. In general, the wastewaters are highly contaminated with organics with BOD_5 concentrations as high as 11,500 milligrams per liter. The ratio of BOD_5 to total COD averaged 0.60. The concentration of phosphorus indicated that the higher yield biological treatment processes might be nutrient limited. Additional alkalinity may be required to support the inorganic carbon demand if the organic nitrogen is nitrified.

Wastewater Sources and In-Plant Control

After completion of the effluent analysis, a detailed in-plant sampling was conducted to determine the source of pollutants. This included collecting weighted composite samples of the egg washer overflow and sump contents, continual overflow from the egg breaker and flushing of vats, tanks, strainers, piping and pasteurizer. Other sources of wastes included rejected inedible eggs from the washer and breaker operations that were not deposited in the proper receptacles, egg product dripping from the breaking machine, malfunctioning egg loading device on the egg washing machine, leaking pumps and piping connections and vat spillovers. All of the latter losses are examples of unmeasurable losses which were referred to as floor losses. Examples of the comparison of the total to various sources is shown in Figure 6.

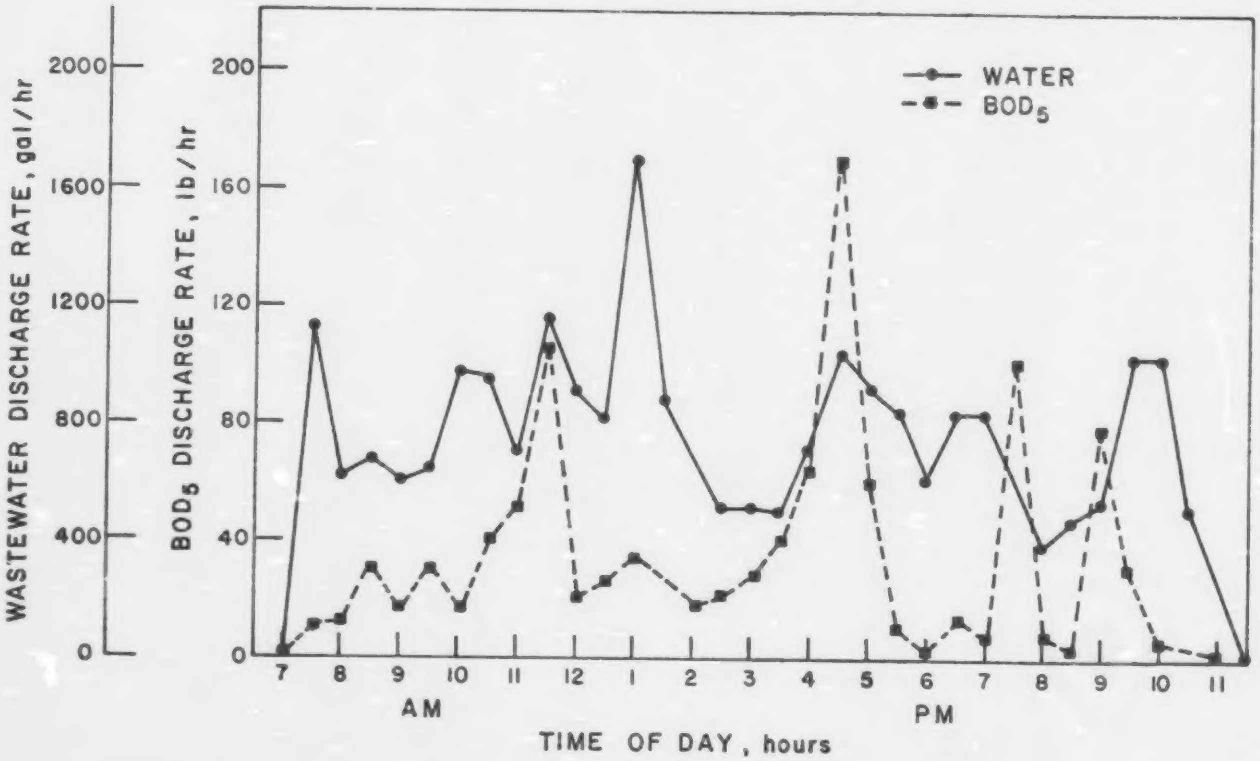

Figure 5. Example of water usage and organic losses (BOD$_5$) in Plant B before in-plant modifications.

Table 2. AVERAGE EFFLUENT WASTEWATER CONCENTRATIONS BASED ON 24-HOUR COMPOSITE SAMPLES BEFORE AND AFTER IN-PLANT MODIFICATIONS FOR WASTE CONTROL[a]

Facility	Total solids	Suspended solids	Total kjeldahl nitrogen as N	Ammonia nitrogen as N	Total phosphorus	BOD_5	COD	Total alkalinity as $CaCO_3$
Before								
A	5,580	1,410	520	4.9	41.2	6,400	10,500	380
B	5,450	930	430	8.3	13.7	4,660	7,760	390
C	-	-	-	-	-	-	-	-
After								
A	2,240	520	180	2.9	11.8	1,650	3,200	310
B	4,360	640	310	1.4	10.0	3,660	6,870	375

[a] All values in mg/l.

Table 3. MAXIMUM RANGE OF POLLUTANTS MEASURED IN EGG BREAKING WASTEWATERS IN PLANTS A, B AND C[a]

Parameter	Range of Value
Total solids	1,400-5,910
Suspended solids	180-1,750
Totak kjeldahl nitrogen, as N	84-630
Ammonia nitrogen, as N	Trace-17.9
Total phosphorus, as P	6.0-59.4
Total alkalinity as $CaCO_3$	260-1,160
BOD_5	590-11,500
COD	1,600-17,900

[a] All values in mg/l.

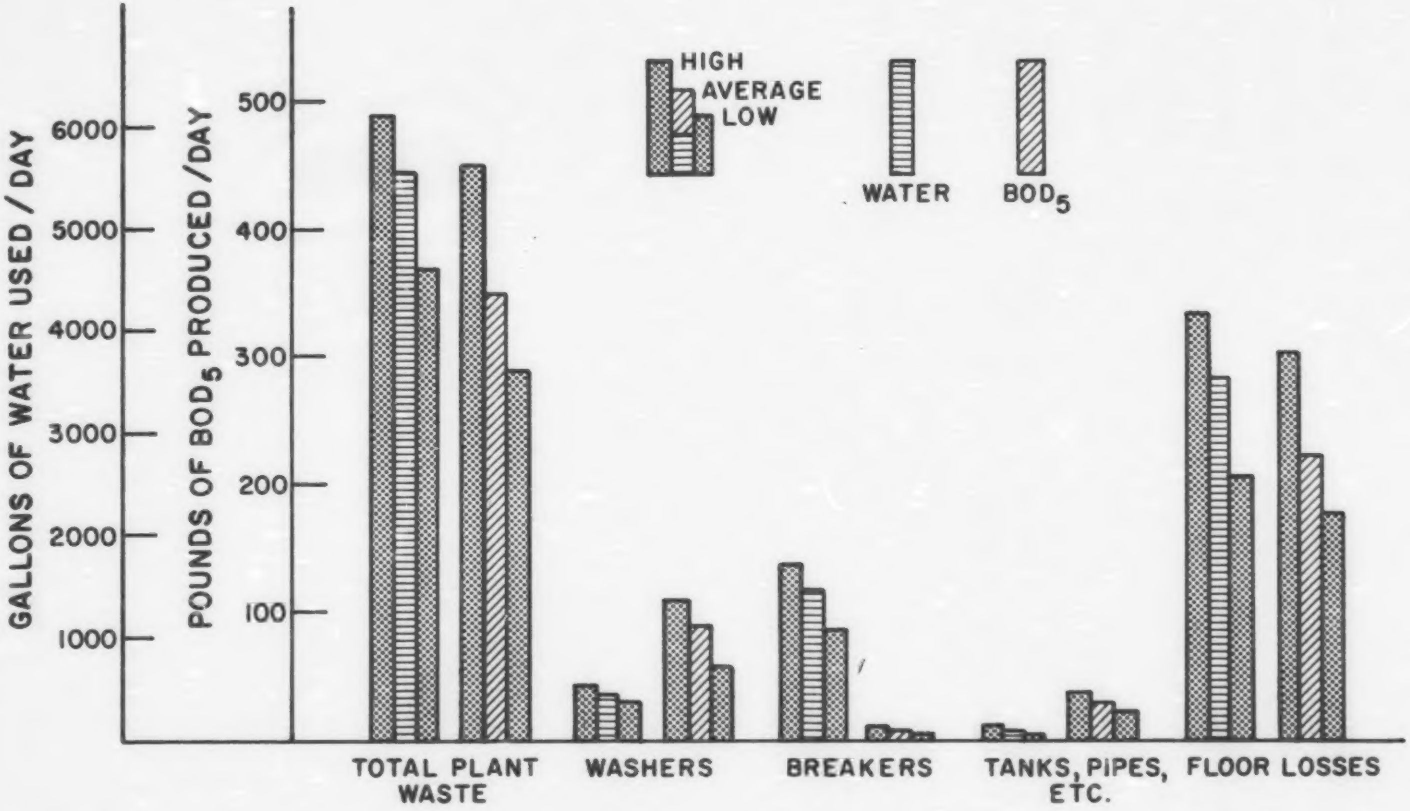

Figure 6. Unit operations contribution of waste of egg breaking wastes before in-plant modification for waste reduction in Plant A.

Although the egg washers contribute only 5 to 10 percent of the plants total wastewater, the BOD_5 loss represented from one quarter to one half the total plant loss. Since the total volume of egg washing water in a medium sized facility (three breakers, for example) would be about 500 gallons per day, it seemed appropriate to consider removing this entire stream from the sewer. The water use shown in Figure 6 for the egg breaking machine is excessive due to malfunctioning of a float valve. A breakdown of the relative quantities of organic wastes and their sources is illustrated in Figure 7.

In-Plant Modifications

Informing management of the weight of BOD_5 lost in their operation provides little understanding or motivation for decreasing the losses. A more effective approach is to relate BOD_5 or COD losses to the loss of egg product that can be easily translated to dollar losses. Although it is difficult to achieve, construction of a mass balance of all materials around a facility indicates the relationship of various losses to the quantity of final product. The mass balance for Plant A shown in Figure 8 is an average of three separate days of sampling in which the total weight of material passing out of the plant was 5 percent less than the measured total input weight. The losses of egg product to the sewer represent a daily loss of about $440 in revenue for Plant A. This was an important observation since this magnitude of loss represents a significant portion of the income of the plant.

Analysis of the waste source survey resulted in developing 13 steps that could be taken to control wastes by in-plant management (Table 4). Although the degree of adoption of the steps shown in Table 4 could not be determined, Plants A, B and C attempted to implement those identified as 2, 3, 4, 6, 11 and 13. In essence, each plant manager adopted the changes which he could implement quickly at a low cost. It was estimated that the cost of the plant modifications was less than $300. The egg washwater was segregated from the sewer and placed in a sanitary landfill along with the shells.

The resulting change in concentration of some pollutant was presented earlier in Table 2. However, the reduction of wastes must be determined using the total weight losses. For Plant A, the percent of material lost to the sewer was about 6.3 percent of processed egg before efforts were made to control waste losses. This was reduced to an average loss of 1.7 percent using in-plant management (see Table 5). The total amount of edible egg liquid did not change, but the animal food recovered increased by nearly 5 percent. It was estimated that the degree of waste control achieved in Plant A represented about 80 percent of the control that is practically feasible. A summary of all water and BOD_5 losses before and after modification is shown in Figure 9. The

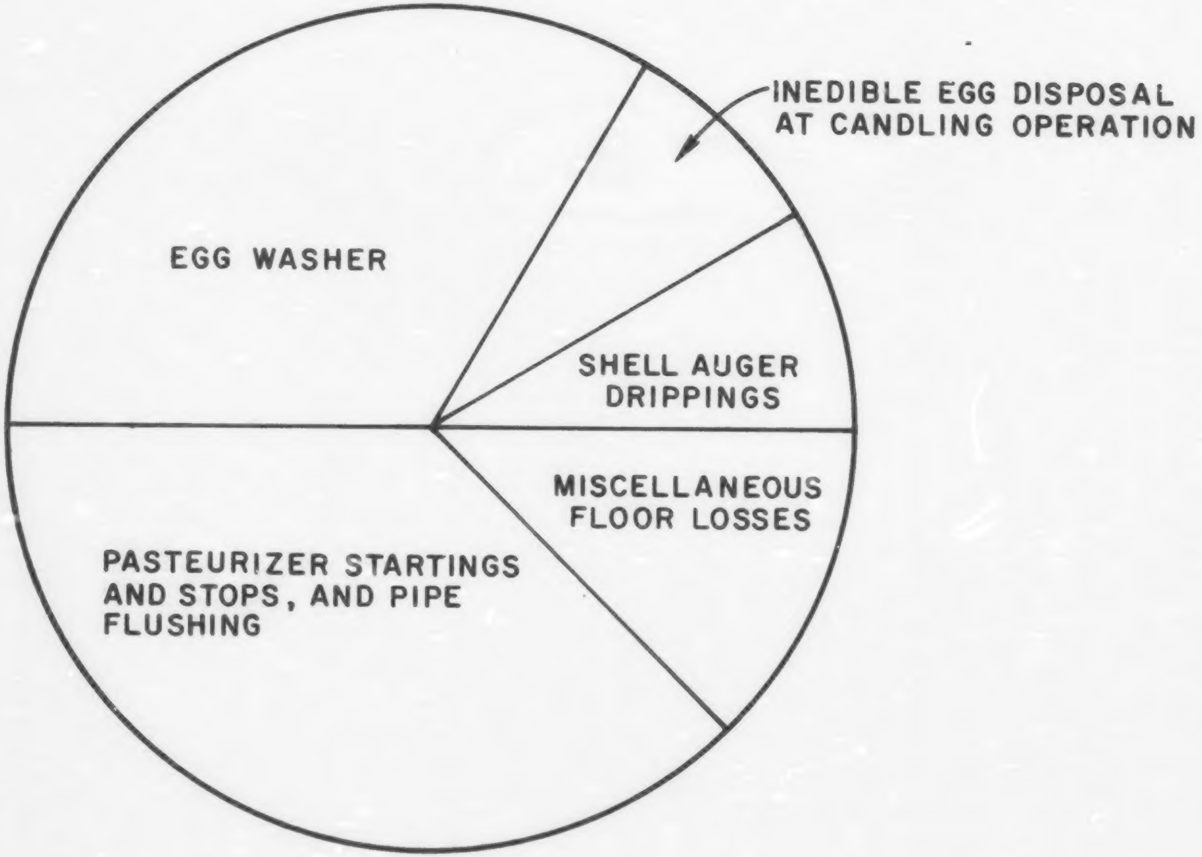

Figure 7. Approximate sources of organic waste loads generated in egg breaking facilities.

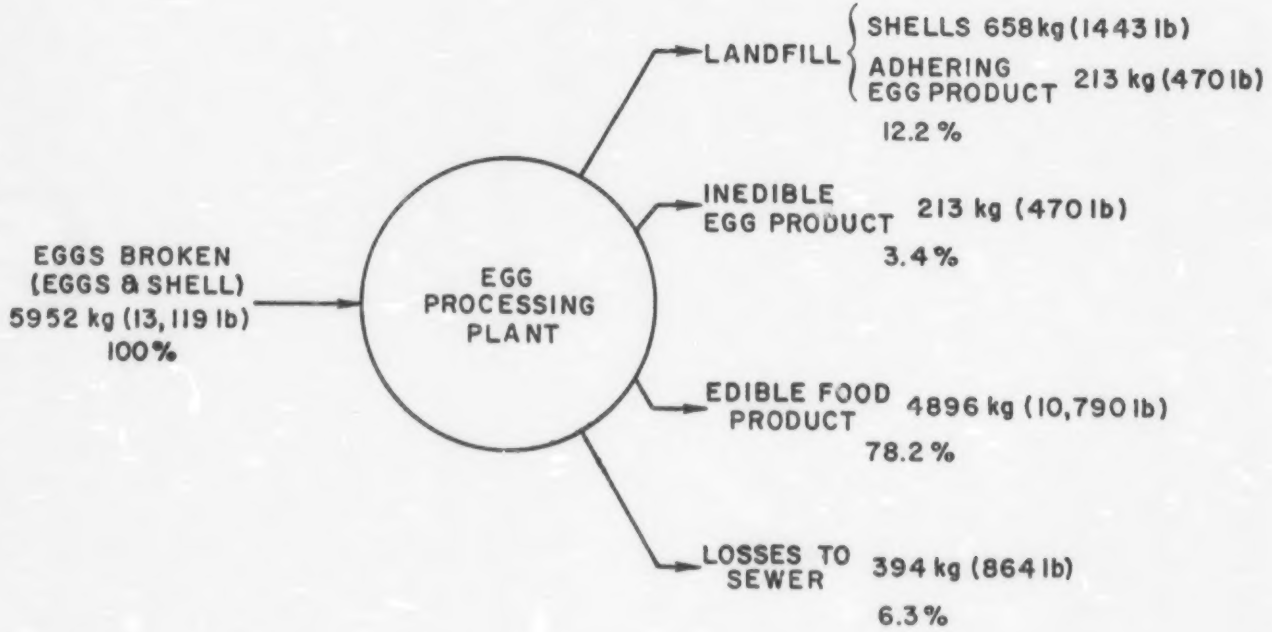
EGGS BROKEN
(EGGS & SHELL)
5952 kg (13,119 lb)
100%
EGG
PROCESSING
PLANT
LANDFILL
SHELLS 658kg (1443 lb)
ADHERING
EGG PRODUCT 213 kg (470 lb)
12.2 %
INEDIBLE
EGG PRODUCT 213 kg (470 lb)
3.4 %
EDIBLE FOOD
PRODUCT 4896 kg (10,790 lb)
78.2 %
LOSSES TO
SEWER 394 kg (864 lb)
6.3 %

Figure 8. Mass balance of egg materials in processing Plant A before waste control modifications.

Table 4. RECOMMENDATIONS FOR MINIMIZING WASTE GENERATION IN EGG BREAKING FACILITIES

1. Minimize use of improper stacking of eggs in storage, or weak storage boxes.
2. Minimize number of times eggs handled and length of conveyor system.
3. Efficient collection of discarded eggs.
4. Frequest adjustment of brushes in washers to minimize breakage.
5. Frequent inspection of egg breaking carrying trays to insure efficient collection.
6. Collection of shel attached albumen from conveyance system.
7. Eliminate storage vat spillovers.
8. Reduce lengths of product lines.
9. Minimize usage of water in plant clean-up.
10. Efficient removal of egg solids from storage units prior to rinsing.
11. Recovery egg chalazaes and gelatinous egg solids from egg strainer.
12. Recovery of initial flush of blend tanks and pasteurizer.
13. Segregate and recover or dispose on land the overflow and sump discharge from egg washing.

Table 5. COMPARISON OF MASS BALANCES OBTAINED FOR EGG BREAKING OPERATIONS IN PLANT A BEFORE AND AFTER MODIFICATIONS FOR WASTE CONTROL

Modifications	Fate of input Fraction of total throughput, % Shells and adhering albumen	Animal food	Edible food	Loss to sewer
Before	12.2	3.4	78.2	6.3
After	12.2	7.9	77.3	1.7

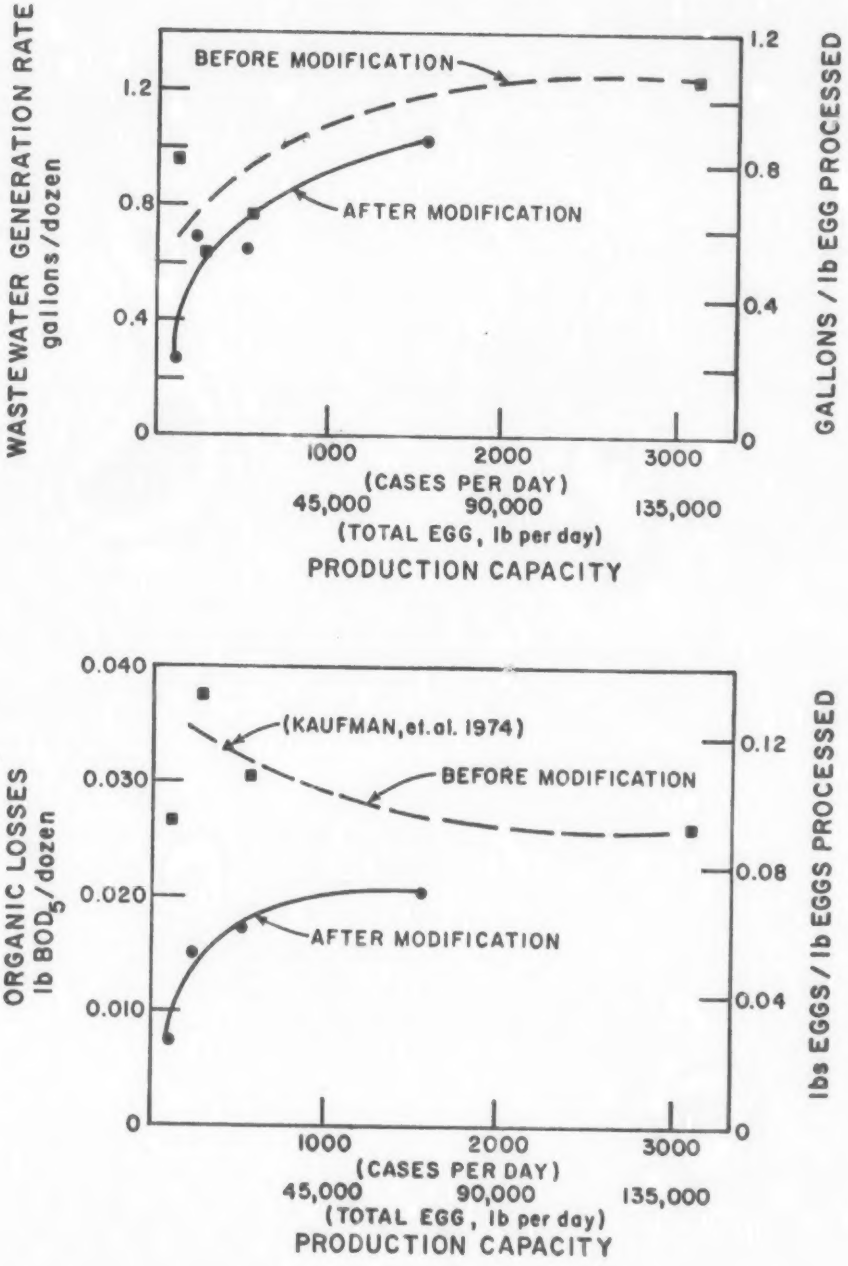

Figure 9. Summary of the average organic and water volume losses before and after plant modifications for waste control.

average quantity of eggs lost in all facilities before modification was about 12.5 percent of the liquid egg processed, whereas, average losses after use of in-plant management was 6.4 percent. In-plant control of wastes were capable of decreasing water useage by about 26 percent and BOD_5 reduction by more than 50 percent.

TREATABILITY

Treatability studies were conducted on wastewaters from egg breaking operation in New York State. Samples were obtained from two plants (Plant A and Plant B) after first reducing the plants' waste loads through in-plant modifications.

In considering possible solutions to the effluent problem, the small size of each individual facility must be kept in mind. The largest facility has a production capacity less than 150,000 dozen per day (about 180,000 pounds per day) and a total design waste flow of less than 200,000 gallons per day. This flow is equivalent to the sewage from a community of 2,000 people. It is especially difficult to provide an efficient and inexpensive waste treatment system for such small but highly contaminated waste flows. Thus, limitations of this portion included development of efficient, inexpensive and simple waste treatment approaches that could provide varying levels of treatment.

Initial emphasis was placed on the use of aerobic system such as aerated lagoons and activated sludge because it was felt that disagreeable odors would rule out the use of anaerobic processes. However, anaerobic lagoons were examined because of their small energy and maintenance requirements. As will be shown, anaerobic processes were surprisingly efficient and did not generate the expected unpleasant odors.

Four types of treatment systems were examined in this study---aerated lagoons, activated sludge, anaerobic lagoons and rotating biological contactors. Inexpensive means of improving the efficiency of treatment with a combination of anaerobic and aerobic lagoons were examined. Also since the effluent from egg breaking plants was highly biodegradable, it was felt that incorporation of mixing theory by having several small completely mixed units in series, as opposed to one large unit, would be advantageous and this concept was also examined.

Methods and Procedures

The aerated lagoons were simulated using a 20 liter reactor with a surface area of 2.5 square feet. The system was innoculated with mixed liquor from a local activated sludge sewage treatment facility. The lagoons were fed on a fill and draw basis, ususally once per day, with distilled water added to account for evaporation losses. The multiple compartment units were the same as the aerated lagoons with baffles added. The activated sludge system consisted of a 5.5 liter reactor followed by an 800 ml clarifier. Substrate was fed continuously to the activated sludge model over a 16-hour period. Solids were wasted from the clarifier in order to maintain a specific solids retention time (SRT).

The rotating biological contactor (RBC) was made up of four sections with a total of 36 polyethylene discs (effective surface area of 250 square feet). The liquid volume was 136 liters. This unit was located at Plant B and fed continuously while the egg breaking facility was in operation.

The anaerobic-aerobic series lagoon treatment was tested using a volume of 30 liters in the first unit and a second unit with a hydraulic detention period of six days. Feed for all units was obtained from either Plant A or B after in-plant modifications had been completed. All feed samples were composited over an entire working day.

The egg processing wastes which were fed to the various treatment processes and the resulting treated effluent were analyzed for a number of characteristics. Total solids, total alkalinity, ortho-phospate and BOD_5 determination were made in accordance with procedures outlined in Standard Methods.[5] Ammonia and Kjeldahl nitrogen were determined as described by Prakasam et al.[6] Both nitrogen analyses are identical to procedures presented in Standard Methods except for the use of micro-Kjeldahl digestion and distillation equipment. COD values were obtained by use of the COD test presented by Jeris.[7]

Additional analyses performed included suspended solids, by use of a Millipore filter apparatus and #9-873B (2.4 centimeters in diameter) Reeves Angel glass fiber filters. Dissolved oxygen determination and oxygen uptake were determined by a Y.S.I. Model 54 D.O. meter. Effluent turbidity of certain treatment processes was determined using a Hach Model 2100 turbidmeter.

Aerated Lagoons

Examples of the performance of the aerated lagoons is shown in Figure 10. The BOD_5 loading rate on the 30-day HRT aerated lagoon was 120 pounds per acre per day or about 8 pounds per 1,000 feet of reactor. Nitrification was more than 90 percent complete, with from 0 to 4.6 milligrams per liter NH_3-N and 0.1 to 4.5 milligrams per liter NO_2-N appearing in the effluent. Oxygen uptake rates decreased from 25.3 to

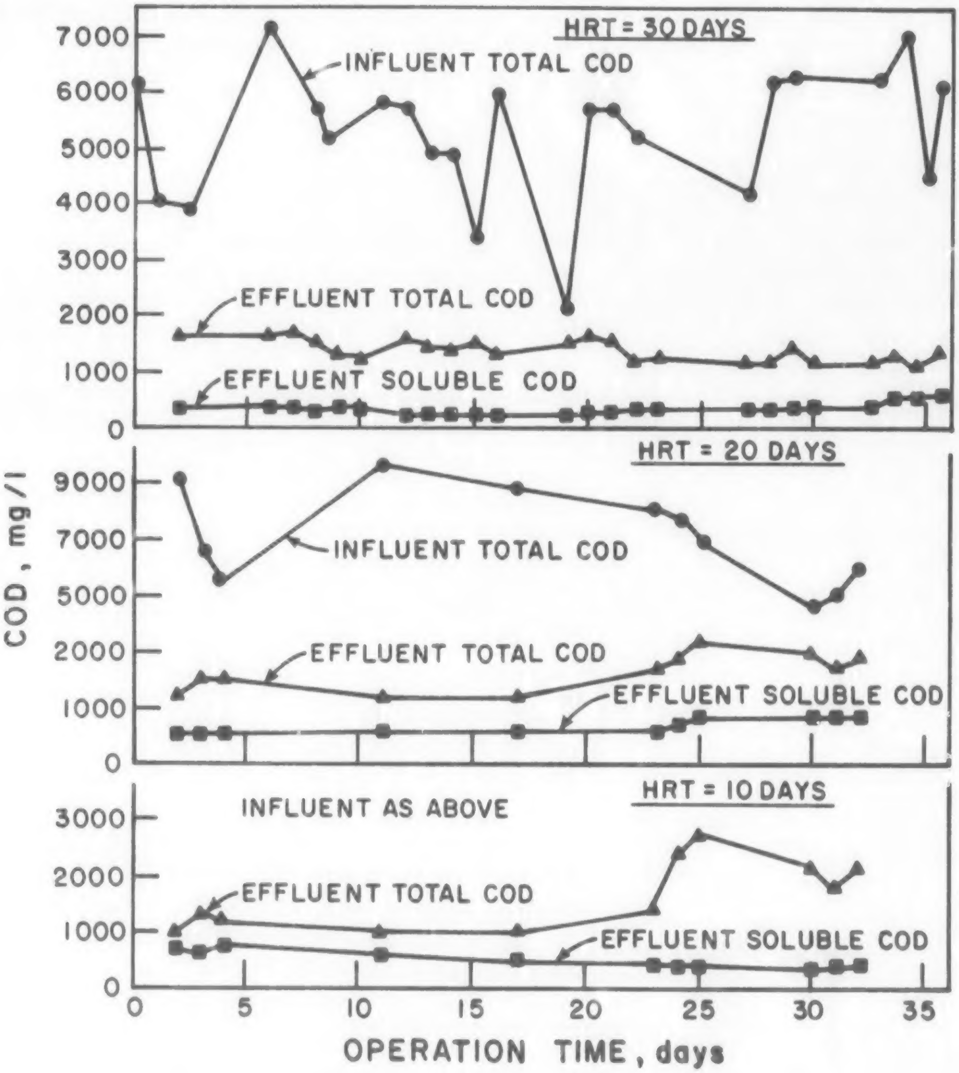

Figure 10. Aerobic lagoon treatment of total egg breaking wastewater from Plant B at 20°C.

7.0 milligrams per liter per hour as the hydraulic retention period increased from 10 to 30 days. The aerated lagoons were capable of reducing a total influent COD ranging from 4,000 milligrams per liter to greater than 6,000 to a soluble effluent less than 700 milligrams per liter at all three hydraulic retention periods. The effluent from all units was characterized by fine nonsettling suspended solids (SS) varying from 560 to 1,300 milligrams per liter. The SS in the effluent imparted a highly turbid yellow appearance to the effluent. Even though these results indicate that this process is capable of soluble COD removal efficiences greater than 90 percent, the effluent quality will probably not satisfy most discharge requirements.

Graphical kinetic analyses were conducted to determine the substrate removal coefficient, K, base 10, COD basis at 20 degrees C. For substrate from Plant A and B, the removal coefficient was 0.76 day^{-1} (least square regression coefficient r = 0.90) and 0.58 day^{-1} (r = 0.97), respectively.

Activated Sludge

It was anticipated that treatment of egg breaking wastewaters with the activated sludge process would be difficult because of the high strength of the wastes. In order to achieve an acceptable organic mass loading it was necessary to maintain the hydraulic detention period longer than four day. The data shown in Figure 11 illustrates that the effluent quality was similar to the effluent from the aerated lagoons.

The sludge in these units settled poorly and high effluent tubidities (70 to 100 Jackson Turbidity Units, JTU) indicated that this process would be a poor choice for the treatment of egg breaking wastes.

Data accumulated from the bench scale operations were used to estimate yield, endogenous respiration and oxygen utilization coefficients. Yield coefficients were 0.245 and 0.300 mg cells per mg COD removed (soluble COD basis), endogenous respiration coefficients were determined to be 0.060 and 0.043 day^{-1}, and oxygen use coefficients were 0.583 for a' and 0.164 day^{-1} for b'.

The activated sludge process is capable of producing an effluent suitable for discharge to a joint treatment system without resulting in a surcharge for excessive oxygen demand or suspended solids. However, problems with settleability of the sludge should be anticipated with this system.

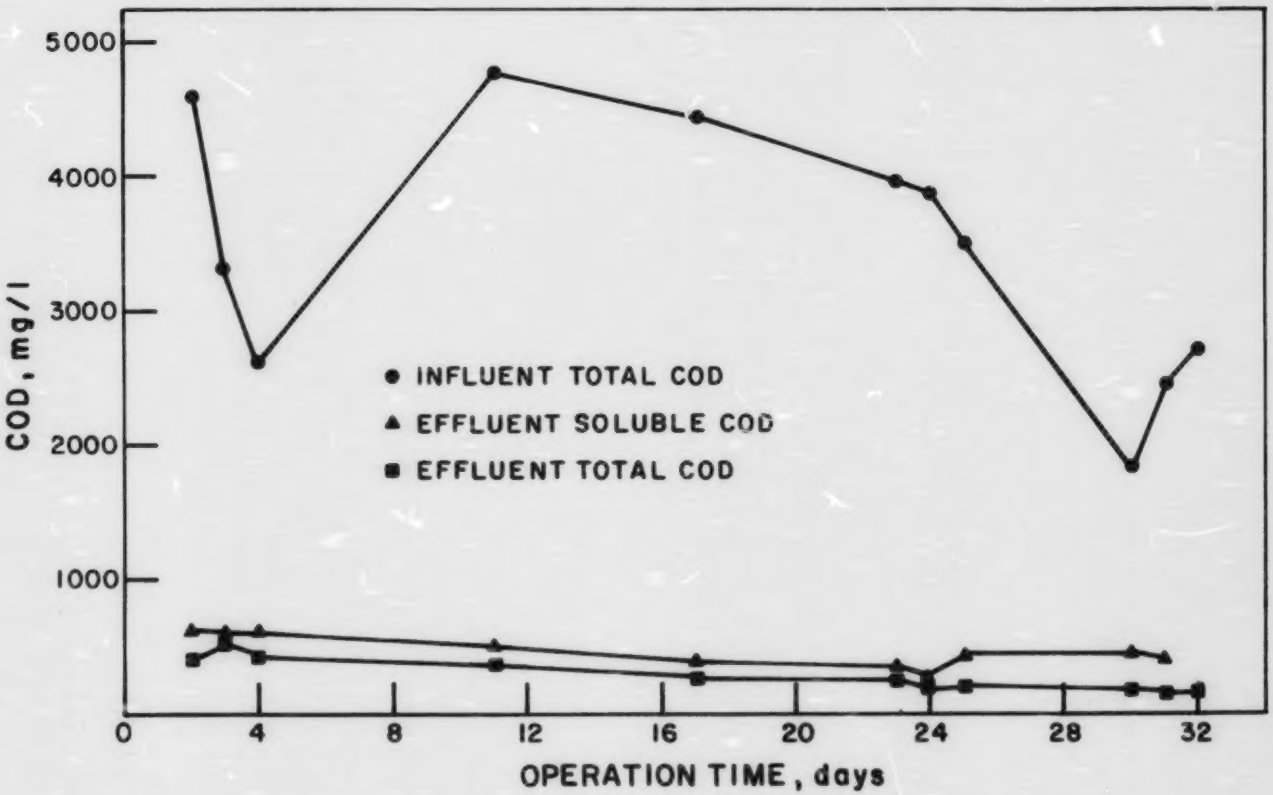

Figure 11. Activated sludge treatment of wastewaters from Plant B at 20°C.

Rotating Biological Contactor

A final aerobic treatment process investigated was the rotating biological contactor (RBC). All of the previous treatment schemes involved suspended growth systems whereas the RBC is an adhered growth treatment unit. This system is similar to the previous processes in that excess solids are produced by the oxidation of the substrate and have to be removed from the effluent.

Table 6 summarizes the results obtained with the RBC study. The pH of the effluent varied from 7.2 to 7.7 without any deficits in total alkalinity. Regardless of the loading rates used (1.4 to 7.3 pounds COD per 1,000 feet) there was always a dissolved oxygen level in all of the four RBC cells.

The RBC units are capable of producing effluents suitable for further treatment and at low loadings can produce effluents with turbidities less than 27 JTU.

Anaerobic-Aerobic Series Treatment

Since the activated sludge process and aerated lagoons were continuously producing effluent with high turbidity, dispersed biological flocs and residual color, additional alternatives needed to be developed in order to provide higher quality effluents. Thus, anaerobic lagoons were examined.

Anaerobic lagoons by themselves would not be acceptable in many instances because of the oxygen demand associated with the discharges from anaerobic processes. Thus, all anaerobic lagoons were followed in series with aerobic lagoons operated at a six-day detention period. Another concern with the anaerobic process was that low temperatures would cause depressed removal efficiencies. Thus, comparative studies were conducted at 20 and 10 degrees C.

The data shown in Figure 12 is representative of the capability of the combined system. A total hydraulic retention period of 26 days reduced a total influent COD of 6,000 to 8,000 milligrams per liter to between 5 and 15 milligrams per liter soluble BOD_5. This system also resulted in an effluent which contained large flocs of rapidly settling suspended solids leaving a clear effluent.

Data for all units are summarized in Table 7. All soluble COD removal efficiencies exceeded 98 percent.

Similar graphical analysis for substrate removal coefficient, K, was conducted for the anaerobic lagoons as for the aerobic lagoons. The

Table 6. ROTATING BIOLOGICAL CONTACTOR TREATMENT CHARACTERISTICS WHEN APPLIED TO EGG BREAKING WASTES FROM PLANT B[a,b]

Parameter	RBC loading rates		
Volumetric (gal/1,000 ft^2/day)	40	80	160
Organic (lb COD/1,000 ft^2/day)	1.38	3.3	7.02
HRT, days			
Influent characteristics			
COD, total	4,150	4,690	5,490
TKN, total	225	182	262
Clarified effluent characteristics			
COD, total	320	350	760
COD, soluble	200	170	240
SS	45	104	304
pH	7.7	7.2	7.2
Alkalinity as $CaCO_3$	365	301	457
DO	7.8	6.4	4.1
TKN, total	29.7	54.5	63.8
NH_3-N	1.5	16.3	17.0
NO_2-N	1.9	4.1	42.5
NO_3-N	11.5	3.4	60
JTU	27	56	86
Observed sludge production, mg solids produced in clarified effluent per mg COD removed	0.123	0.149	0.035
Removal efficiency, %			
COD, total	92.3	92.5	86.1
COD, soluble	95.1	96.3	95.7
TKN, total	86.8	70.0	75.6

[a] Operating temperatures were 21 to 24 degrees C.

[b] All units in mg/l unless otherwise noted.

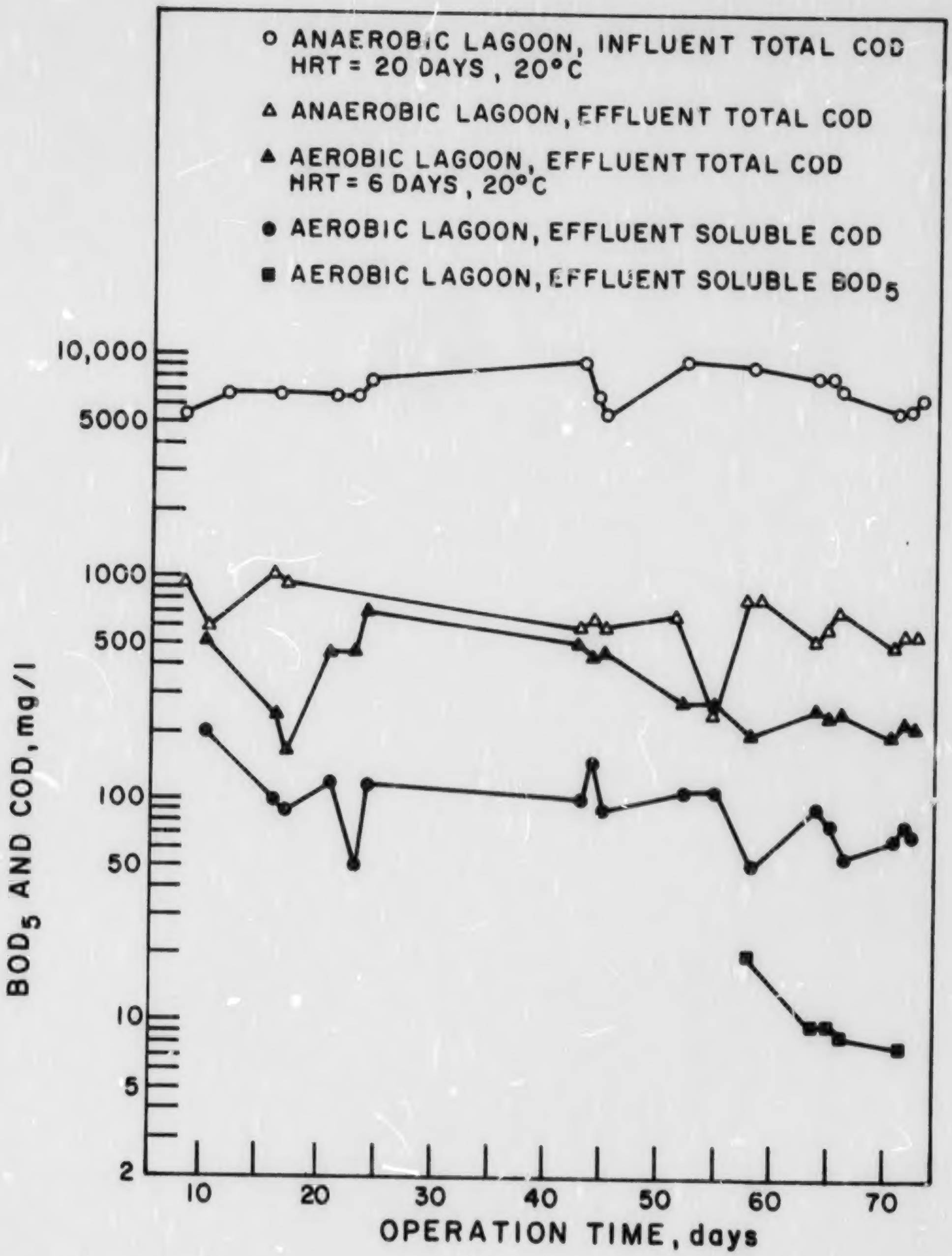

Figure 12. Series lagoon treatment with 20-day HRT at 20°C in the first anaerobic lagoon and 6-day HRT at 20°C in the aerobic lagoon.

Table 7. CHARACTERISTICS OF THE ANAEROBIC-AEROBIC LAGOON SERIES TREATMENT SYSTEM

Parameter	System number				
	1	2	3	4	5
Temperature, °C	20	10	20	10	20
HRT					
Anaerobic unit	20	20	10	10	5
Aerobic unit	6	6	5	6	6
System effluent soluble COD, mg/l	90	66	72	86	72
Removal efficient, total COD, %	98.7	98.4	98.5	98.1	96.7
Effluent turbidity, JTU	4.8	9.1	-	21.4	-

20 degree C anaerobic lagoon K was found to be 0.63 day^{-1}. This was very similar to the removal coefficients obtained for the aerobic lagoon treatment of wastes (0.76 and 0.58 day^{-1} for Plants A and B, respectively). This procedure was not applicable to the lower temperature units because the effluent characteristics of the units studied were similar. However, the observed efficiencies at 10 and 20-day hydraulic retention periods at 10 degrees C were similar to that observed at 20 degrees C. Thus, it can be concluded that there was little effect on the substrate removal coefficient between 10 and 20 degrees C. The greatest difference occurred in the loss of nitrification activity at 10 degrees C.

Perhaps the most impressive characteristics of the combination anaerobic-aerobic lagoon system was the high clarity and highly flocculated nature of suspended materials in the effluent from the aerated unit. In no case did the total effluent turbidity exceed 10 JTU for units operated at 20 and 10 degrees C. Since all solids settled rapidly, the soluble BOD_5 values shown in Figure 12 of about 10 milligrams per liter are indicative of the efficiency that this treatment combination is capable of achieving with an influenct COD varying between 5,000 and 10,000 milligrams per liter and a total system hydraulic detention period of 26 days.

Multi-Cell Versus Single Cell Systems

Egg wastewaters are highly biodegradable and for this reason can be treated by various combinations of systems. Utilization of multi-cell units enables the use of smaller systems to achieve the same treatment efficiency. Data supporting this statement are illustrated in Figure 13. Total COD removal with a one-cell aerated lagoon at ten-day HRT achieved 60 percent removal efficiency, whereas a five-cell aerobic lagoon with the same overall HRT achieved a removal efficiency of 83.5 percent and a five-cell anaerobic unit with a ten-day HRT obtained a removal efficiency of 91 percent. Thus, this data indicates that addition of individual compartments to lagoons treating egg breaking wastes will improve the efficiency for any given volume. However, to protect the system against shock loads, it is suggested that no more than three cells be used for any lagoon.

Lagoon Sludge Accumulation

Although design of the sludge handling facilities was beyond the scope of this study, empirical approximations of the quantities of sludge accumulated in both the anaerobic and the aerobic lagoons would assist in determining the feasibility of this system. The data for measured sludge accumulation in these systems are summarized in Tables 8

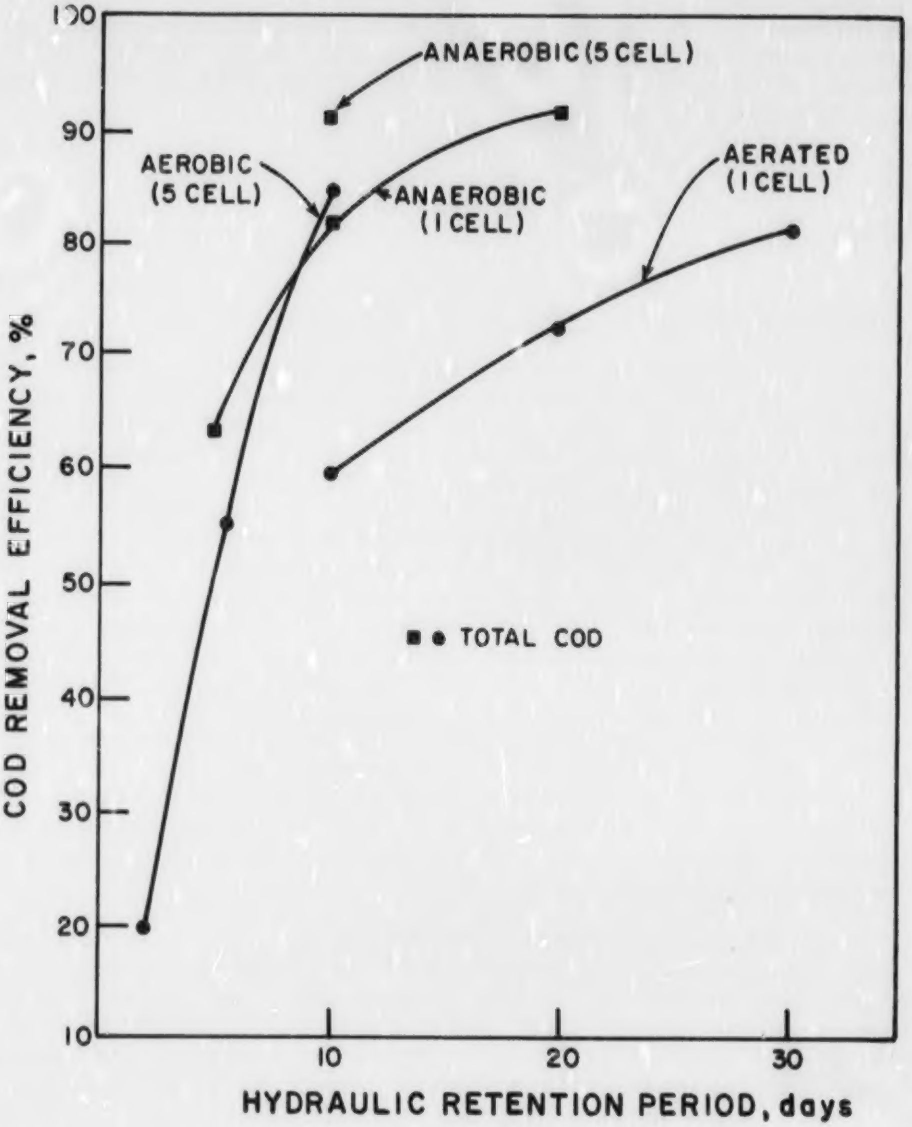

Figure 13. Comparison of multi-cell and single cell aerobic and anaerobic treatment processes at 20°C.

and 9. The quantity of solids accumulation was expressed as a fraction of the solids added for the anaerobic lagoon, and as a percent of the total flow volume treated for the aerobic lagoons. In all anaerobic units operated at 20 degrees C, the accumulation of solids was low and represented about 5 percent of the solids added. The higher accumulations at 10 degrees C reflects lower rates of stabilization. However, bioprecipitation of the solids in these units enable the treatment efficiency at the lower temperatures to be nearly equal to that at 20 degrees C.

DISCUSSION

Egg Breaking Waste Generation and In-Plant Controls

The average facility that did not practice in-plant waste control was found to lose 12.5 percent of its processed product to the sewer. This level of product loss agrees with a recent survey of plant practices in the United States where average loss was reported to be 12.1 percent with the maximum range of 4 to 25 percent.[4] Several facilities with losses less than 4 percent were reported but discarded in the survey.[4] In the instances with the New York facilities, it was found to be relatively simple and inexpensive to reduce the loss from 12 percent down to 6 percent, and in one case down to 3 percent on a long-term basis. On the basis of this analysis, it was concluded that of the total losses of around 12 percent, about half are readily controlled by good in-plant management. Of the remaining wastes (6 percent), 3 percent can be removed by careful management and further implementation of some of the more costly suggestions shown in Table 4. This level of in-plant control would provide 75 percent BOD_5 reduction and would be considered difficult to achieve by many facilities on a long-term basis. It is estimated that product losses in the industry could be controlled at about 2 percent with high quality management using all recommendations given in Table 4.

The maximum range of water and product loss for all plants was 0.43 to 1.41 gallons per dozen and 0.0048 to 0.0478 pounds BOD_5 per dozen eggs processed (0.0062 to 0.058 pounds BOD_5 per pound liquid egg produced), respectively. On the average, more than one egg per dozen processed goes to ths sewer in 0.9 gallons of water. The water use compares well with the United States survey[4] where the range was 0.485 to 3.27 gallons per dozen eggs processed with an average of 1.49 gallons per dozen eggs. A survey of three Dutch plants reported water use to be 0.49 to 1.56 gallons per dozen eggs.[8] But the Dutch study reported the amount of product loss varying from 0.5 to 4.2 percent.

Table 8. MEASURED SLUDGE SOLIDS ACCUMULATION RATE IN ANAEROBIC LAGOONS

Anaerobic lagoon operating conditions		Solids accumulation rate
HRT, days	Temperature, °C	% of total solids added per day
10	10	30
20	10	68
5	20	12
10	20	6.0
20	20	5.4

Table 9. MEASURED SLUDGE VOLUME ACCUMULATION RATE IN EFFLUENTS FROM 6-DAY HRT AEROBIC LAGOONS FOLLOWING ANAEROBIC LAGOONS

Pretreatment anaerobic lagoons		Aerobic lagoon temperature, °C	Sludge volume accumulated, % total volume treated
HRT, days	Temperature, °C		
10	10	10	1.7
20	10	10	3.7
20	20	20	2.7
10 (5-cell)	20	20	1.2

In large plants (10 to 12 breakers), it may be uneconomical to collect and land dispose 9,460 to 13,625 liters (2,500 to 3,600 gallons) a day of the highly contaminated egg washing waters. An alternative solution might be to try to recover the protein either by drying, chemical precipitation, or heat treatment.

Since the major contributor to egg losses in the breaking industry is the egg washer, it seems logical that larger plants with multiple breakers could set aside one of its breakers to be preceded by a washer, to handle "dirties", and the remainder of the breakers could be operated without washers. Kraft et al.[9] have shown that commercially processed whole eggs contain similar bacterial population counts. The same study concluded that product contamination is instead highly dependent upon sanitation practices during clean-up operations.

Results of bacteriological studies conducted in this study show that bacteria counts in egg washing liquids increase enormously over the four-hour run periods. In fact, the data suggests that in some cases egg washing appears to contaminate egg surfaces rather than clean them.

The advantage of breaking eggs without first washing them is that egg processors will reduce the amount of egg product lost to the sewer and at the same time recover an inedible by-product. Assuming that egg processors lose 0.04 pounds COD per dozen eggs of which 25 percent results from washers and 5.83×10^8 dozen eggs are broken annually, it is estimated that 12 million pounds of inedible liquid egg could be recovered by eliminating washers. Further study needs to be conducted on this possible change in processing.

Four of the five plants surveyed disposed of empty egg shells by trucking them to local sanitary landfills on a daily basis. One of the plants used an incineration system to reduce the moisture content of the shells from 30 percent to 2 percent. Air drying collects and retains the nutrients present in the adhering liquid portion of the shell,[10] and may be an asset when sold to poultry feed producers.[11] Assuming 20 million cases of egg at 47 pounds per case are processed each year, 11 percent of an egg's weight is shell, the egg breaking industry has capabilities of providing nearly 53,000 tons of dried egg shells products annually.

Although egg breaking accounts for only 11 percent of the nation's eggs and grading operations, the remainder, the pollution potential of the processing industry is greater than that of the grading process. BOD_5 losses from the grading operation of Plant C amount to 0.001 pounds BOD_5 per dozen eggs graded. Hamm et al.[12] indicated that egg grading losses average 0.0014 pounds BOD_5 per dozen occur in egg grading plants. Therefore, egg breakers handle a small portion of the country's eggs, but the losses per dozen are tenfold higher than losses of grading operations.

Treatability of Egg Breaking Facility Wastewaters

This treatability study encompassed a variety of aerobic and combination anaerobic bench scale treatability units. It is evident that the high degree of treatment of egg processing wastewaters for the purpose of direct discharge to surface waters can be achieved most easily by the combination anaerobic-aerobic lagoon treatment. Anaerobic-aerobic lagoons are advantageous from the standpoint of low maintenance requirements, energy requirements and capital costs. Treatability studies have shown that the two-lagoon system is capable of producing an effluent of low turbidity with good solids settling characteristics and extremely low oxygen demand substances. These results are illustrated in Figure 14. Thus, the treatment system which was found to be most effective in controlling the egg breaking wastewater is shown in Figure 15.

There are a number of design considerations involved with full-scale operation of anaerobic-aerobic systems. Bench scale studies indicated that a scum layer will form on the anaerobic lagoon and retain odors associated with the system. It is not known how stable this scum layer will be under field conditions.

Another possible drawback of these systems is the possible impact of low temperatures on treatment plant efficiency. At temperatures lower than 10 degrees C, the removal capacity of this combination may be diminished even though the organic removal efficiencies were nearly the same at 10 degrees C as they were at 20 degrees C.

The design procedure for the lagoons is simplified because of the fact that the substrate removal coefficient, K, was nearly the same for anaerobic and aerobic lagoons (0.63 day^{-1} versus 0.67 day^{-1}, respectively), and also because there appeared to be no significant effect in effluent total COD quality when the temperature was decreased from 20 to 10 degrees C.

Oftentimes municipal systems utilize aerobic treatment processes. If an industry such as an egg breaking plant discharges to this particular plant, there may be difficulty in meeting regulatory effluent guidelines. Experience from this study indicated that poor effluent quality can be expected when treating egg processing wastes aerobically. Thus, municipal aerobic plant upsets may occur when egg breaking plants contribute sizeable portions of the total organic loading. In the town where Plant E is located, there does not seem to be a problem with the operation of the municipal trickling filter, but the egg processing

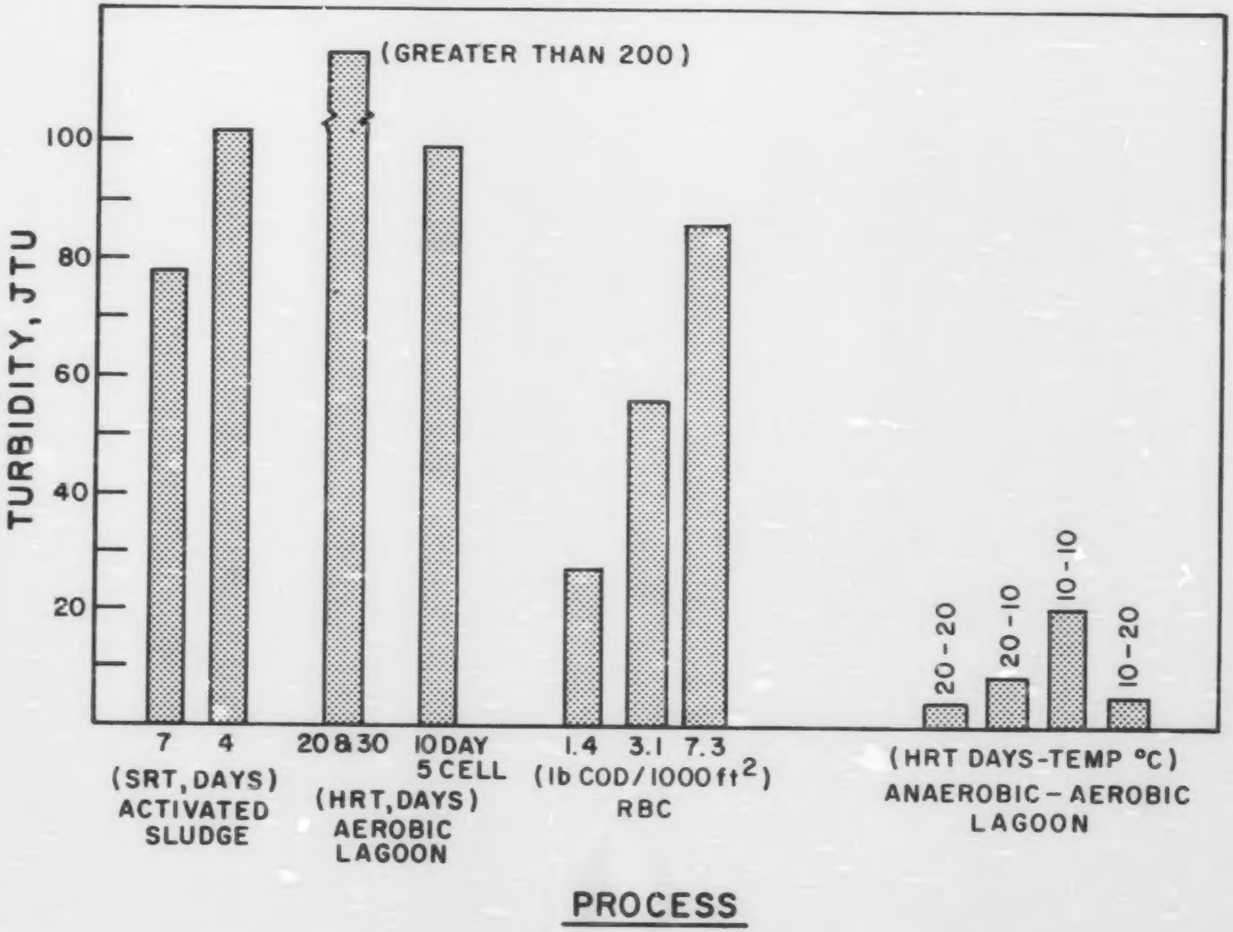

Figure 14. Summary of effluent turbidity from various aerobic and anaerobic-aerobic treatment systems.

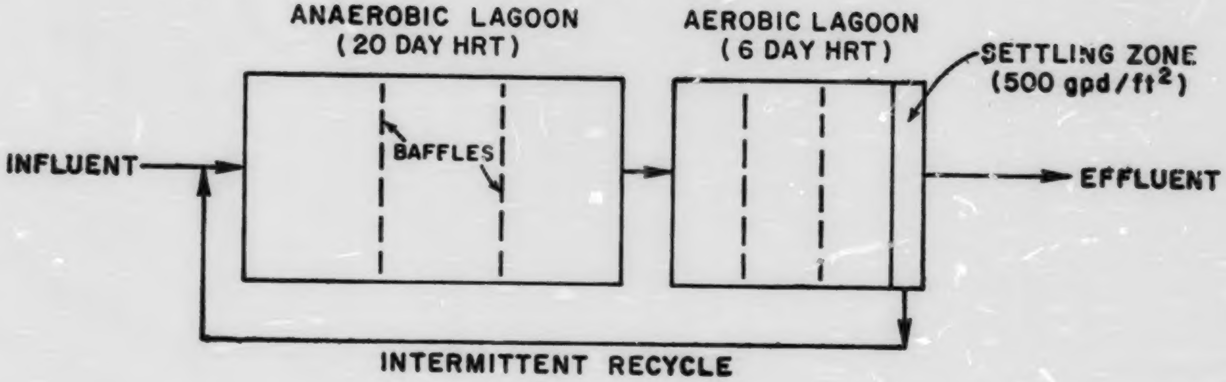
ANAEROBIC LAGOON
(20 DAY HRT)
AEROBIC LAGOON
(6 DAY HRT)
SETTLING ZONE
(500 gpd/ft^2)
INFLUENT
BAFFLES
EFFLUENT
INTERMITTENT RECYCLE

Figure 15. A recommended wastewater treatment system to achieve maximum organic pollution control of egg breaking wastewaters.

wastes constitute less than 10 percent of the municipality's organic loading.

CONCLUSIONS

1. Eleven percent of eggs produced in the United States go to egg breaking plants, resulting in 2.9 x 10^8 kilograms (6.40 x 10^8 pounds) of liquid egg products which grossed $195 million in 1969.

2. Most egg breaking plants are located in small communities. The highly contaminated wastewaters generated in egg breaking industries can cause difficulties in municipal treatment facilities. In the five egg breaking plants sampled, the wastewater ranged between 8 percent and 1,500 percent of the wastes generated from all other sources in the communities in which they were located.

3. Wastewater characterization indicated a highly contaminated discharge with COD's greater than 6,000 milligrams per liter, and BOD_5 equal to about 60 percent of the COD. Although the nitrogen content exceeded requirements for aerobic biological treatment, the wastewater was phosphorus deficient. It was also slightly deficient in alkalinity required to support efficient nitrification.

4. Up to 15 percent of the total egg liquid output was lost to the sewer in plants where good in-plant management was not practiced. Losses equivalent to three eggs for every dozen broken were reported as maximum losses that occur in plants where no waste conservation measures were practiced. The average pre-modification product loss in all five plants sampled was 12.5 percent (by weight) of the processed output.

5. The measured average amount of liquid egg recovered per dozen eggs broken was 0.55 kilograms (1.21 pounds) and this represented recovery of 80 percent of the total egg weight.

6. The average egg liquid loss in a medium size facility (two or three breakers) represents a decrease in revenue between $500 and $700 per day.

7. The losses on a product basis averaged as follows: Before in-plant waste conservation 0.034 kilograms BOD_5 per kilogram egg liquid produced and wastewater volumes of 7.5 liters per kilogram (0.90 gallons per pound) egg liquid produced. In-plant modifications

decreased average BOD_5 losses by 50 percent and decreased wastewater volume by 24 percent.

8. In-plant waste control was found to reduce the waste generated from an average of 12.5 percent product loss to 6.4 percent product loss. This is equivalent to additional egg product recovered worth between $250 and $500 per day in a medium sized breaking facility, not including the savings from reduction in cost of waste treatment.

9. Adoption of in-plant waste control measures that cost less than $300 per plant could result in reduction of waste load equivalent to about two-thirds of that which is technically achievable. Good plant management appears to be capable of reduction of product loss to about 5 percent of the liquid egg output. If more extensive and costly modifications are made to the plant to recover the first flushing from pasteurizers, pipes, and tanks, the product loss to the sewer could probably be reduced to less than 2 percent of the output.

10. On a national basis, in-plant waste control would result in annual product recovery of 3.2×10^7 kilograms (7×10^7 pounds) of liquid egg of a quality suitable for animal food which is now lost to the sewer.

11. Egg breaking wastes as obtained from three facilities, A, B and C, were highly biodegradable with no observed toxic effect to biological treatment processes.

12. High concentrations of organic material were not reduced to levels acceptable for direct discharge to surface waters in conventional processes, such as activated sludge and aerobic lagoons; even at low design loadings.

13. Aerobic lagoons, with hydraulic retention times of 30 days reduced the total COD from 5,800 milligrams per liter to 1,000 milligrams per liter, and resulted in a high effluent turbidity.

14. When an anaerobic lagoon was followed by a six day HRT aerobic lagoon, the overall COD removal efficiency was greater than 98 percent, at 20 degrees C and 10 degrees C, and at anaerobic lagoon HRT's of 5, 10, and 20 days. Effluent quality from the aerobic lagoon in a series system operating at 20 degrees C with a 20 day HRT anaerobic primary unit averaged as follows: 90 milligrams per liter soluble COD, 13 milligrams per liter soluble BOD_5, 92 milligrams per liter NO_3-N, 21 milligrams per liter NH_3-N and turbidity of 5 JTU.

15. Design capacity should be related to maximum production capacity that can be achieved when eggs are plentiful during the months of May and June. In most facilities wastewater flows are very low at night and during weekends.

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PULP RECOVERY FROM TOMATO PEEL RESIDUE

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SUMMARY

Caustic peeling of tomatoes results in the loss of food material and creates waste material. By altering the peeling process and subsequent operations, it is possible to increase the amount of recovered food material and simultaneously reduce the quantity of organic wastes which are normally discharged. A similar situation exists with the tomato juicing operation where there is a food-grade material discharged with the pomace residue that results from the extraction-finishing operations. Collectively, the peel and pomace residues that go to waste disposal in California amount to about 400,000 tons per year. About half of this tomato residue can be recovered as food-grade material.

This paper describes proposed development and evaluation of a marketable product. Mechanical removal with rubber discs of the skin from caustically peeled tomatoes will reduce water usage so that the peel can be separated into concentrated pulp and skin fractions. The alkaline pulp fraction can be neutralized in a variety of ways, either directly with acid, or by combining with acid-treated macerate. The resulting puree-pulp can then be merged with tomato pulp from other regular plant operations and used as a puree-pulp, hot sauce, catsup, etc. By appropriate processing, a food-grade product can be produced from what otherwise would be lost as a waste.

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INTRODUCTION

Casutic Peeling

A peeling operation to remove skin materials is a necessary step in the processing of numerous fruits and vegetables before preservation by freezing or canning. Volume wise, caustic peeling is the most prevalent. It is commonly done on peaches, tomatoes, and potatoes by exposing the produce to a caustic solution and then following this by a wash using large volumes of water to remove the softened outer skin and residual caustic. This washing not only removes the outer skin but also some of the underlying edible flesh. Where operations are conducted by this conventional caustic peeling, the liquid effluent is frequently a primary source of pollution in the plant's total waste flow.

The development at the Western Regional Research Center (WRRC), Berkeley, California, of an infra-red, or "dry caustic", peeling process for white potatoes has contributed to a significant reduction of the quantity of waste water pollutants generated during the peeling of potatoes.[1] Through this process, which has been widely adopted by the potato processing industry, potato peel can now be recovered and converted to cattle feed, thereby creating a by-product from what was previously a waste material.[2]

The technology has been successfully modified and applied to a variety of other caustic-peeled commodities, such as peaches.[3] However, the utility of recovered peel material varies widely. Where by-products are of limited value, the costs for process modification and operations are often prohibitive. Where no present use for the by-product exists, the recovered material must be discarded, usually to a sanitary landfill or other land-disposal site.

Peel material, whether potato or tomato, is difficult to handle because the reduction in wash water leaves a peel residue with a pH 11 to 12 and a high sodium content. High pH material is abnormal to waste treatment plants, and it may require a neutralizing pretreatment with acid if sufficient dilution is not available. The high sodium content is not desirable in the California Valley areas which may already be borderline for crop sodium tolerance. An example is the San Luis drain canal from the lower San Joaquin Valley, which brings high-mineral field drainage about 150 miles from the lower valley to where the seawater reaches inland. From the environmental view, solid peel-waste disposal may merely be transferring the liquid-disposal problem to an intermediate solids-disposal problem if there is eventual runoff from the disposal site. The solution is to reduce peel waste at the point of origin.

Tomato Processing

Caustic or lye peeling of tomatoes involves submerging the fruit for about 30 seconds in a 16 percent sodium hydroxide bath at about 200 degrees F. A significant quantity of edible tissue is removed along with the peel. The total resulting residue is significant in terms of quantity, reduced recovery, and cost. For example, during 1974 about 6.3 million tons of tomatoes were harvested for processing in California; this was 80 percent of the total United States processing-tomato harvest. Of this 6.3 million tons in California, about 90 percent, or 5.7 million tons, were processed by plants located in the Sacramento and San Joaquin river basins, which drain into San Francisco Bay. Of this California tonnage, an estimated 15 percent, or 850,000 tons, was peeled, primarily by conventional, water-intensive methods; this resulted in a 20 percent weight loss, or a total of 170,000 tons of tomato material (6 percent solids on a wet basis). This may also be regarded as the generation of an equivalent weight of organic pollutants which must be removed from the water through subsequent treatment prior to the discharge of these processing waste waters to receiving streams. These same problems exist, albeit to a lesser extent, in other parts of the country, e.g., Ohio, Indiana, New Jersey, where tomatoes are processed.

The Food and Drug Administration (FDA) Standards of Identity under 21 CFR 53.10, 53.20, and 53.30 for tomato pulp/puree allow this material to be from one of three sources. One source is the liquid obtained from the residue from preparing such tomatoes for canning, consisting of peelings and cores, with or without such tomatoes or pieces thereof. This, then, is a consideration for the utilization of pulp recovered from the peeling of tomatoes destined for whole pack; about 15 percent of the commercial tomato pack is whole tomatoes. The remaining 85 percent (5.4 million tons) of California processing tomatoes is processed into tomato juice, puree (pulp), paste, and sauce. The juices used to produce these products are obtained by macerating whole tomatoes, heating, and extracting the pulp and juices with "finishers". A finisher is a screen (sieve) device having mechanical paddles to move the material through the screen. The residue remaining after juice extraction consists primarily of seeds, skin, and fiber, and is collectively referred to as pomace. The utility of pomace in by-products is presently very limited. The bulk of the 200,000 tons (33 percent solids) generated during 1974 was disposed of on land. The balance was dehydrated for use as feed for animals (e.g., fur-bearing) whose parts or products are not destined for human consumption.

Feed use of pomace or peel waste is limited primarily by the presence of insecticide residues in concentrations greater than that now permitted for feed. Currently, the insecticide toxaphene is used on growing tomatoes. This is an oil-soluble material and it tends to be located in the waxy layer of the tomato skin. Since the seeds in the pomace contain about 20 percent protein, skin removal could increase the utility of pomace for feed. The pomace discharged from finishers contains unrecovered tomato pulp similar in quality to the juice passing through the finisher screen. Recovery of the pulp, which adheres to the tomato skin, will not only increase the raw product yield, but may facilitate separation of the skin from the residual seeds and fiber materials.

There are, therefore, two promising areas for recovering additional pulp from tomato residue which is now commonly discarded as waste. One is the pulp in the peeling residue from the caustic peeling of tomatoes destined for a whole-tomato pack; the other is the pulp in the pomace from tomato macerate destined for juice, puree, paste, catsup, and such products going through a finisher. In both cases, the potential of both physical and economical recovery of these pulps is promising, based on laboratory and pilot studies. Successful recovery on a commercial scale will significantly increase production yields while reducing substantially the quantity of pomace which must be discarded. Reduction in residue volume will alleviate environmental problems (vectors, odors, and runoff) associated with land disposal of such wastes. At 200,000 to 250,000 tons per year of pomace residue, and 170,000 tons per year of peeling residue in California alone, there are collectively about 400,000 tons per year of residue available to consider. If half of this 400,000 tons per year is considered recoverable as food-grade material, there are 200,000 tons per year to be considered either as a waste disposal expense or as a usable food. As a waste disposal expense, there is an estimated annual $1 million disposal expense at $5 per ton for caustic material sent to a sanitary landfill. If the 200,000 tons per year is viewed as a food material, the potential value is $12 million, based on a raw tomato value of $60 per ton at the cannery. This is an attractive spread between waste disposal expense and value as a product.

RECOVERY METHODS

Past Tests

Utilization of peel residue was considered during pilot tests in 1973.[4] Peel residue recovered from rubber disc peelers was similar to macerated tomatoes except for its high alkalinity and skin content, and the absence of seeds and core fiber. The peel material, which is removed without additional use of water except for a minimal rinse at most, can be readily segregated and separately handled. This peel material consists primarily of skin and tomato pulp in a ratio of about

1:3, respectively, on a dry-wieght basis, and contains about 0.7 percent sodium hydroxide (wet basis), resulting in a pH 11 to 12. The pulp fraction can be of food quality since most of the cells are intact, and this layer of pulp contains a relatively high concentration of pigment with respect to the whole tomato. Therefore, the pulp represents a significant quantity of recoverable and utilizable material, potentially valuable for food use. In a large scale test conducted in 1974, 124 cases of puree were prepared in commerical equipment.[5] Caustic peel residue containing about 8 percent total solids (TS) was separated into skin and pulp fractions, the skin fraction was discarded, and the caustic pulp fraction was processed further by first neutralizing with food-grade hydrochloric acid. Then, a final puree product was made by mixing the neutralized pulp with conventionally processed pulp and concentrating this misture to 10.5 percent TS. It was tentatively concluded that the product was promising as to color, taste, salt content (from neutralization of the caustic), and the low pesticide residue. Wetting agent content in the product was not determined. Wetting agents are normally used in caustic peeling baths to effect a faster and more uniform action in loosening the peel. There are FDA tolerances on their use, and a marketable product would need to take this into consideration.

Peel Pulp Residue Recovery Methods

To process caustic peel residue into a marketable food product, consideration must be given to separating out the skin if pesticide residues are on the skin, and if product grades are affected by skin fragments. A first step is to separate the caustic peel residue into pulp and skin fractions with a finisher. The pulp passes through the finisher screen and goes on to further processing into food. The skin does not pass through the screen, and is discharged from the finisher as a solid material; this "waste" skin can be combined with other cannery solid waste that is destined for disposal, presumably to a sanitary landfill.

The pH 11 to 12 tomato pulp coming through the finisher screen is quite caustic; there are, however, several ways in which this pulp can be neutralized and eventually incorporated into the main food material stream of the cannery. One is to neutralize the alkaline pulp directly with food-grade hydrochloric acid to the normal pH of processed tomatoes which is about pH 4.3; the new result of this neutralization is the formation of sodium chloride (table salt). This use of acid and the resulting presence of additional salt in tomato materials, is allowed under the FDA Standards of Identity, 21 CFR 53.10, 53.20, and 53.30. Rather than adding acid per se to the peel residue, alternatives can be considered, such as adding previously acidified tomato macerate or pomace. These and other alternatives will now be considered in the following subcategories.

Macerate Treatment---General Description. Several acid treatment processes for tomatoes have been successfully demonstrated by WRRC, and one has received FDA approval. One is called an "acid break"; this utilizes a low pH of about 1.5 to inactivate/inhibit enzyme action, and loosen the pulp cells for increased extraction of pulp beyond that possible through only a hot break. The second, termed "acid treatment", and approved by FDA, involved acidification to pH 2.7 to loosen the pulp cells for increased extraction.[6,7] The third is an adjustment to pH 6 to thicken or increase the consistency (viscosity) of the pulp; this is a useful attribute in sauces and purees.

Macerate Acidic Treatment---The Acid Break, pH 1.5. If the pH of a tomato macerate (crushed, whole tomatoes including skin and seeds) is reduced to about 1.5, two things can be accomplished. First, the normal tomato enzyme is inhibited. These enzymes, if not inactivated in a matter of seconds by means of heat or low pH, will break down the normal tomato consistency that is necessary in most tomato products such as catsup, puree, and sauces. Second, the residual tomato pulp that normally adheres to the pomace after a commercial hot break and finishing is loosened sufficiently so that it will remain with the "juice" during the finishing operation. The result is that additional food-quality tomato solids are recovered to the extent that the finisher pomace solids are reduced by about half. The pomace waste that does remain for disposal or utilization contains about 50 percent total solids. There is, therefore, less tonnage for disposal or, if the material is dehydrated for animal feed, significantly less fuel is required. For example, the energy needed to dry 50 percent moisture material is about 25 percent less than that needed for 63 percent moisture materials. The extracted low pH material may be stabilized by heating to permanently inactivate the pectinolytic enzymes before, or simultaneously with neutralization of the added acid. It can be neutralized with the alkaline peel residue to the mutual benefit of both materials without adding extraneous neutralizing material.

Macerate Acidic Treatment---The Acid Treatment, pH 2.7. Acid treatment of pH 2.7 does not inhibit enzyme action and these enzymes must be adequately inactivated by a hot break as in present day processing. An acid treatment of hot-tomato macerate at pH 2.7 will loosen the pulp cells for increased extraction of pulp beyond that possible by a hot break. Treatment of pH 2.7 loosens and facilitates the removal of residual pulp from the seeds, fiber, and skin to increase pulp recovery and, thereby, reduce pomace waste by about 40 percent. A product with greater consistency (viscosity) than normal can be obtained, but is time-temperature labile. Under current processing practice, where the aggregate time at temperatures about 160 degrees F is less than one hour, a consistency increase can be expected. Beyond two hours, probably no consistency increase will result. This acid-treated pulp can be merged with the alkaline peel residue to restore the normal pH of this mixture to a natural tomato pH of 4.3. On neutralization of pH 2.7 material, sodium chloride is formed; this added sodium chloride amounts to about 0.4 percent. A pH 2.7 material at 70 degrees F is stable for a few hours, which allows a non-neutralized macerate or juice to be transported from a field-juicing site to a central cannery for finish processing. Therefore, the geographic origin of the peel residue and acidified macerate do not have to be the same; they could originate 100 to 200 miles apart. A so-called field, rural, or decentralized tomato preparation and juicing station has the potential advantage of disposing of the wastes from cleaning and pomacing operations back onto a tomato field in the immediate vicinity. The option for partial processing at a decentralized location also moves jobs back to the farm areas, and reduces the transportation damage resulting from hauling raw tomatoes over long distances. Studies have shown that this transit loss can amount to 10 percent or more.

Macerate Alkalinization Treatment---The Alkaline Treatment, pH 6. A pH 6 treatment of macerate gives results somewhat similar to a pH 2.7 treatment, i.e., increased consistency and decreased pomace, due to the removal of more pulp from the seeds and fiber than results from only a hot break. The mechanism and process condition have not yet been sufficiently worked out. Possible the pH 6 treatment gives a higher consistency but a lesser recovery from the pomace.

Pomace Residue Treatment---Acid and Alkaline, pH 2.7 and pH 6. Pulp adhering to tomato pomace can be recovered by either of two pH adjustments: (1) adjusting and holding at about pH 6, or (2) acidifying and holding the pomace at pH 2.7. The acidification approach loosens the tomato pulp cells which adhere to the skin beyond the loosening accomplished by even a prolonged hot-breat. The hot-break, heating to 212 degrees F, inactivates enzymes and also loosens the pulp; this facilitates subsequent pulp extraction from the seeds and fiber in the finisher. A prolonged hot break degrades both color and flavor. As with the pH-treated peel residue, this recovered tomato pulp may be brought back to the natural pH of tomatoes, either by a direct addition of food-grade acid to the pH 6 material, or by adding caustic to the pH 2.7 material; or two streams of "opposite" pH material can be merged, as next described. As another alternative, the pH can be adjusted with the alkaline peel residue.

PROPOSED PLANS

While various methods have been discussed for utilizing the peel residue, pomace, and macerate materials, there are undetermined and unresolved process aspects on yield, rates, time span, recovery, and operating points. This means that it is too early for a commercial installation. On product quality and marketability, questions exist on pesticide residues, wetting agents, microbiology, salt content, color, flavor, consistency, and nutrients. Therefore, further experiments are proposed to provide this information on commercial equipment at full-flow rates. It has been proposed that this work be done as a cooperative effort by several agencies. These organization are: (1) US Department of Agriculture (USDA), Agricultural Research Service, Western Regional Research Laboratory, Berkeley, California, (2) National Canners Association (NCA), Western Laboratory, Berkeley, California, (3) commercial tomato canneries. The particular cannery site(s) are unknown at this time, and the local cannery situation will make considerable difference as to what is experimentally practical. The processing season is mid-July through mid-October. The laboratory and process analysis will take place throughout the year.

Process Considerations

Typical cannery operations process 80 t0 180 tons per hour of tomatoes with 20 to 40 tons per hour undergoing a caustic peeling operation over two to four parallel lines, resulting in 4 to 8 tons per hour of caustic peel residue. The proposed experimental trials will be through a single line using typical commercial equipment, at full flow, but for a short duration so as not to consume undue amounts of materials and time. Packs on the order of 1,000 pounds each will be processed. Full-flow rates are considered important becuase results from reduced flows can be markedly different. Trials will be with controlled temperature, pH, flow rate, residence time, weighed wastes and similar conditions and data that are needed to calculate recovery, make a material balance, and select optimum process parameters. When practicable, the BOD, COD, or TOC will be measured on various waste streams from the conventional (control) and alternate operations. Sanitation considerations are necessary because of the potential microbiological build-up between the peeler and the heating and pH adjustment vessel (Figure 1).

Currently, two commercial types of mechanical disc peel removers are in use on tomatoes. One is a reely type with the disc rotation across or 90 degrees to the reel axis and tomato flow (Magnuson Engineers, Inc., San Jose, California). The others are flat-bed types with the disc rotation parallel with the tomato flow (FMC Corporation, San Jose, California; Melrose Metal Products, Co., Oakland, California;

1. CONTROL---conventionally processed tomato macerate and pulp.

2. NEUTRALIZATION OF PEEL PULP BY ACID---peel pulp directly neutralized with acid to pH 4.2 ± 0.2.

3. NEUTRALIZATION OF PEEL PULP BY ACIDIFIED MACERATE---peel pulp adjusted to pH 4.2 ± 0.2 with acid treated pH 2.7 conventional pulp, macerate, or pomace.

4. ALKALINIZATION OF CONVENTIONAL PULP BY CAUSTIC PEEL PULP---conventional pulp is adjusted to pH 6 with caustic peel pulp. Mixture is then adjusted to pH 4.2 ± 0.2 with acid.

Figure 1. Process options for caustic peel pulp.

and South Valley Manufacturing, Inc., Gilroy, California). Some use water sprays in the peel removal section and some do not. If the peel pulp is to be recovered, the advantage is with the equipment that does not dilute the peel with water and, therefore, gives a "dry" peel with about 8 percent TS. High solids content is desirable for processing as well as effluent disposal. Typically, a flow of 2 tons per hour of peel residue is expected to be available from one peeler, though the actual rate will depend on the particular equipment, operation, and cannery at which the trials are conducted.

Process and flow options for the control, neutralization, and alkalinization procedures are shown in Figures 1 and 2. The primary investigation is to be on the direct neutralization of pH 11 to 12 peel pulp by acid (Option 2); this is to be compared with the "Control" of conventionally processed tomato macerate and pulp (Option 1). Option 3, Neutralization of Peel Pulp by Acified Macerate, is a means of putting the acid to a dual use by first using it to give an acid treatment to otherwise conventionally processed macerate for increased yeild as previously described under "Macerate Acidic Treatment---The Acid Treatment, pH 2.7"; then the acidified macerate is mixed with the peel pulp to mutually neutralize both streams to pH 4.2 ± 0.2. This Option 3 is considered an economy of acid use because it is first used to increase the yield obtained from conventionally processed macerate before using it as a neturalizing agent. Since the increased yield through acid treatment has previously been established,[6,7] Option 3 is a secondary consideration. The "Alkalinization of Conventional Pulp by Caustic Peel Pulp" (Option 4), is of lesser interest than the above measures because there is not sufficient laboratory-scale information available at present to fully define the mechanism and conditions under which pulp yield and consistency are increased. These lesser options will be reduced or expanded, depending on results and available resources. Initially, direct neutralization of the caustic peel pulp by food-grade hydrochloric acid is considered the most practical under commercial processing conditions, and the basic, initial effort will concentrate on this.

Peel pulp is to be merged with conventional or acid-treated pulp in ratios of 1:3 or as much as 1:20, depending on what relative volumes are normal to a cannery's operations. This mixture will then be vacuum evaporated to 8 to 24 percent soluble solids to conform to the needs of tomato puree-pulp or hot sauce. Preliminary results in 1974 indicated that product quality was better in a 1:3 ratio than a 1:0.[5]

Product Considerations

The result of processing the caustic peel residue is considered to be a marketable product containing salt, and used in formulating tomato

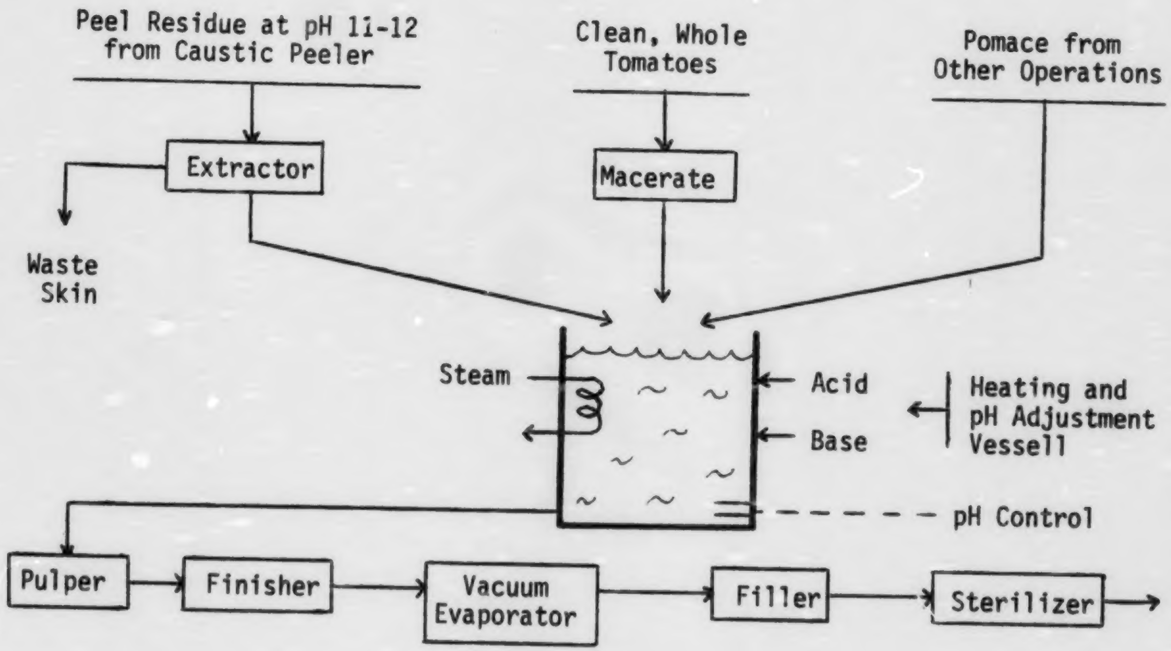
Peel Residue at pH 11-12
from Caustic Peeler
Extractor
Waste
Skin
Clean, Whole
Tomatoes
Macerate
Pomace from
Other Operations
Steam
Acid
Base
Heating and
pH Adjustment
Vessell
pH Control
Pulper
Finisher
Vacuum
Evaporator
Filler
Sterilizer

Figure 2. Flow diagram.

puree, catsup, pizza sauce, or other concentrated tomato products. Initially, an 8 percent soluble solids (SS) puree will be made, though the experimental range is considered to be that of a tomato puree-pulp which contains 8 to 24 percent SS and conforms to the USDA Quality Grade Standard 50-5081 for puree-pulp. The salt levels resulting from the neutralization of the sodium hydroxide in the peel pulp blended with conventional pulp are compatible with such products as salted puree-pulp, hot sauce, pizza sauce, catsup, etc. Hot sauce is a more universally marketed product that salter puree-pulp; as a market item, it might be the more attractive end product. Salter puree-pulp would seem to conform to the FDA Standard of Identity 21 CFR 53.20, though presumably an actual ruling on the process, ingredients, and labeling is the preferred method by which to introduce a new process and product.

Samples are to be collected by both NCA and WRRC in order to determine overall product quality, salt, solids, consistency, color, nutrients, and residues of pesticides, wetting agent, etc. Since toxaphene is commonly used to spray tomato fields, and it tends to remain in the waxy layer of the skin, the quality of the separation of peel skin from the peel pulp is crucial. A direct analysis of the product is to be made for toxaphene and other insecticides.

A somewhat similar need exists to know whether or not if wetting agents are carried over into the product. It is current, general commercial practice to add a wetting agent to the caustic peeling bath to aid peeling speed and uniformity. At present, it is not known how stable the wetting agents are during the peeling operation, and whether their effective disappearance during the peeling operation is due to: (a) decomposition, (b) entrainment with the tomatoes, or (c) some other cause. Typical compounds approved by FDA (21 CFR 121.1091), for use as wetting agents in peeling baths and in current use are: heptanoic acid, sodium 2-ethylhexyl sulfate, sodium n-alkylbenzene sulfonate, etc. At this time it appears that an analytical method to directly measure the wetting agent, if any, in the final product may need to be developed.

CONCLUSIONS

In conclusion, these proposed tests will determine the feasibility of recovering food-grade tomato pulp from caustic peeling residue. This pulp is to be used in a marketable, salted product such as a puree-pulp, hot sauce, pizza sauce, catsup, or other concentrated tomato product.

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PROTEIN PRODUCTION FROM CHEESE WHEY FERMENTATION*

Chu H. Tzeng**
Douglas Sisson**
Sheldon Bernstein**

INTRODUCTION

The magnitude of the whey disposal problem in the United States has been documented elsewhere.[1] Suffice to say, while great strides have been made in its utilization and recovery, whey still represents a tremendous source of potential pollution. Raw whey, as it is drained from the cheese vats, has a BOD_5 of 30,000 to 50,000 parts per million and should be recovered and utilized in some manner to avoid the very great cost of pollution abatement. It may be condensed, dried, fractionated or demineralized---all processes which produce products taking advantage to varying degrees of the protein, lactose and minerals present. The huge volume of raw material, however, often causes problems due to the large capital investment necessary for sophisticated equipment and a limited specialized market. It is not unusual for a single cheese factory to produce 1 million pounds or more of liquid whey a day, a source that cannot be turned on or off at will, and the total amount produced annually in this country is approximately 30 billion pounds.

One of the few industries capable of utilizing these large volumes is the animal feed industry. Unfortunately, the price that can be paid for dried whey for feeding purposes is low, often just about the processing costs. This is because the major constituent of dried whey is lactose which can be used only in a limited amount in most feeds and must compete price-wise with other inexpensive carbohydrate and energy sources such as molasses and corn. There is a much greater demand for high protein ingredients in this area. This report describes the commercial conversion of the lactose in whey into high quality protein via fermentation.

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This work, initiated and partially supported with funds from a demonstration grant from the US Environmental Protection Agency, shows how this can be accomplished in a unique closed-loop system producing zero effluents. By this process one may utilize very large amounts of whey, a potential environmental contaminant and convert it to a useful product which can be used in an industry capable of absorbing the large amount of material produced---that is, the animal feed industry.

PROCESS AND RESULTS

The fermentation of whey by various microorganisms has been know and studied for years. Our own preliminary studies, reported elsewhere,[2,3] showed that the organism of choice in our process is a strain of Saccharomyces fragilis. The conversion of lactose into yeast cellular material is efficient and in the range of 45 to 55 percent under non-sterile conditions. Successive scale-up has been accomplished from shake-flasks to 14-liter fermentors to 500 gallon and 3,000 gallon fermentors to our present operation in a 15,000 gallon tank.

Whey (acid and/or sweet) is obtained in concentrated form (45 to 50 percent solids) from cheese manufacturers. This is diluted with water, raw whey or condensate water (as in "closed-loop" operation, to be described shortly) to the appropriate lactose concentration. Other medium additions include: anhydrous ammonia as the primary exogenous nitrogen source, phosphoric acid, yeast extract and hydrochloric acid to adjust the pH to 4.5. The medium is heated to 80 degrees C for 45 minutes and then cooled. The fermentation is carried out in a 15,000 gallon stainless steel deep-tank fermentor that is fully aerated and jacketed. Automatic instrumentation controls pH, temperature, aeration and foaming, as well as levels and volumes in and out. The fermentor may be operated in a batch, semi-continuous or continuous manner. After fermentation, the fermented whey mass is collected and processed further. An overall schematic of the fermentation process may be seen in Figure 1.

In a batch fermentation, starting with a seed with a viable cell count of 1×10^9 cells per milliliter and an inoculum level of 10 percent, all the lactose is utilized in 8 hours under appropriate conditions with an increase in cell concentration of 10 to 20 fold.

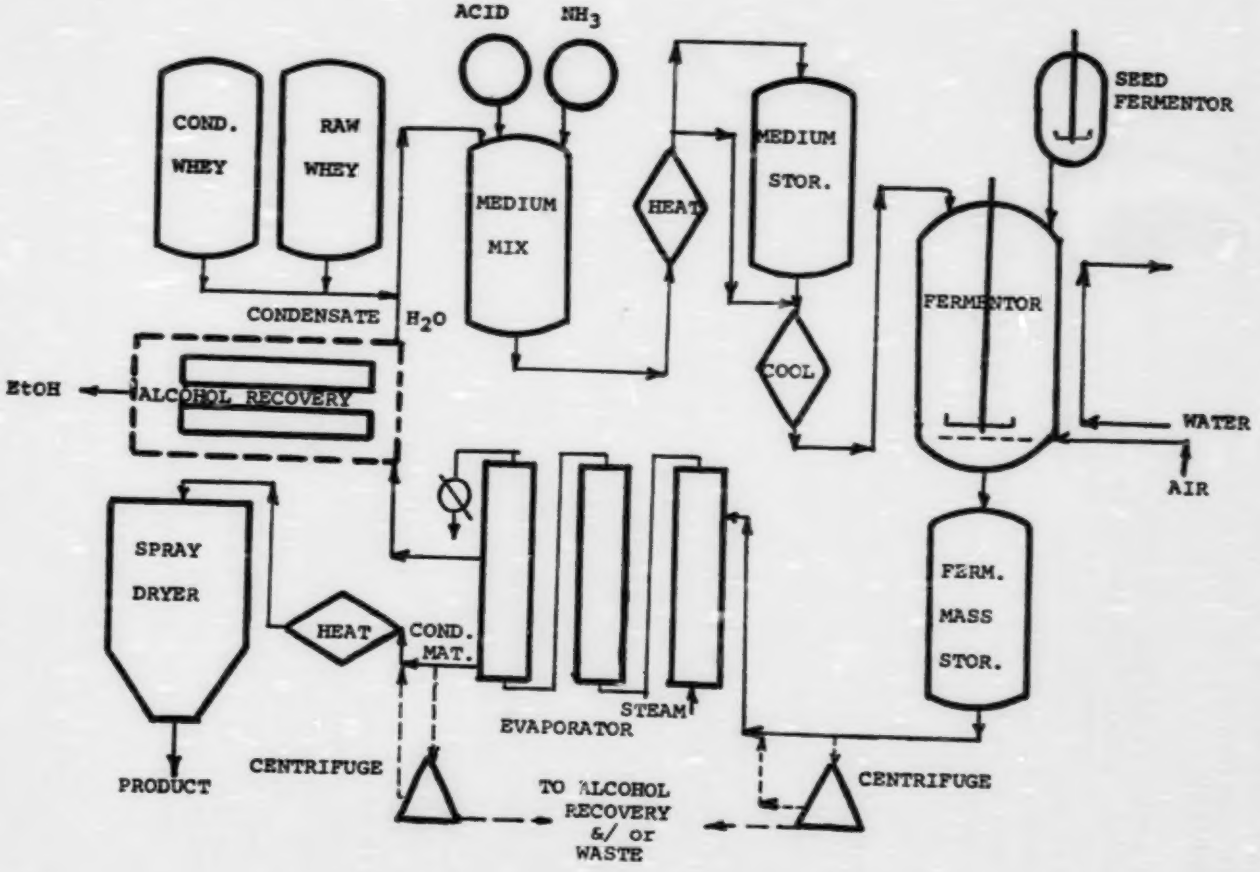
ACID
NH3
COND. WHEY
RAW WHEY
MEDIUM MIX
HEAT
MEDIUM STOR.
COOL
SEED FERMENTOR
FERMENTOR
WATER
AIR
CONDENSATE
H2O
EtOH
ALCOHOL RECOVERY
SPRAY DRYER
HEAT
COND. MAT.
EVAPORATOR
STEAM
FERM. MASS STOR.
CENTRIFUGE
CENTRIFUGE
PRODUCT
TO ALCOHOL RECOVERY &/ or WASTE

Figure 1. Schematic for whey fermentation process.

This represents a generation time of approximately 2.0 hours and four doublings within an 8 hour period.

The semi-continuous runs were made by drawing off 90 percent of the fermentation broth and using the 10 percent remaining to seed the next fermentation batch. A number of consecutive draw down batches could be run in this manner. The only "down-time" experienced in such a procedure is the time it takes to pump off 90 percent of the fermented broth and to pump in fresh medium.

This "down-time" can be eliminated if the fermentation can be run continuously, i.e., with continuous addition of fresh medium and the removal of the fermented mass. The most efficient industrial fermentations are of this type. This proved to be applicable in our yeast-whey fermentation. The continuous fermentation is begun when the cell count in the fermentation broth reaches 1 x 10^9 cells per milliliter and the lactose concentration falls to 0.50 to 0.75 percent (W/V). At this time fresh medium is added and fermented whey mass removed at an equal rate. The fermentor may be operated in this manner for an extended period of time, maintaining both cell count and lactose concentration at a relatively constant level, without any indication of contamination or buildup of metabolic products that would interfere with the fermentation. In the smaller tanks, continuous runs of several weeks have been accomplished. The 15,000 gallon fermentor has been operated in this manner for shorter periods with no difficulty, other than the initial start-up logistics. One of the early runs in the large tank is shown in Figure 2. After initial cell growth, fresh medium is added and the fermented whey mass removed at the rate of 1,250 gallons per hour, which corresponds to a batch fermentation cycle of 10,000 gallons per 8 hours (dilution rate of 0.125 hours^{-1}).

The production of *Saccharomyces fragilis* on whey has been done in the United States on a small scale[4] and is approved for use in feeds and foods.[5] The entire fermented whey material (Yeast Fermentation Solubles, YFS) can be used as a feed ingredient. This simplifies the processing for it entails only the concentration of the fermentation broth and spray drying. If the yeast cells are harvested by centrifugation and washed, a food grade, primary grown yeast is obtained. The proximate analysis of these products are shown in Table 1.

The use of these products as feeds or foods and the quality of the protein they contain are indicated by rat feeding tests. Rat growth rates using YFS and centrifuged YFS as the sole protein source in the diet were compared with those using a casein standard. No evidence of toxicity was noted during this period of time. From these experiments, Protein Efficiency Ratios (PER) were calculated and found to be 1.72 for the whole Yeast Fermentation Solubles and 2.26 for the centrifuged

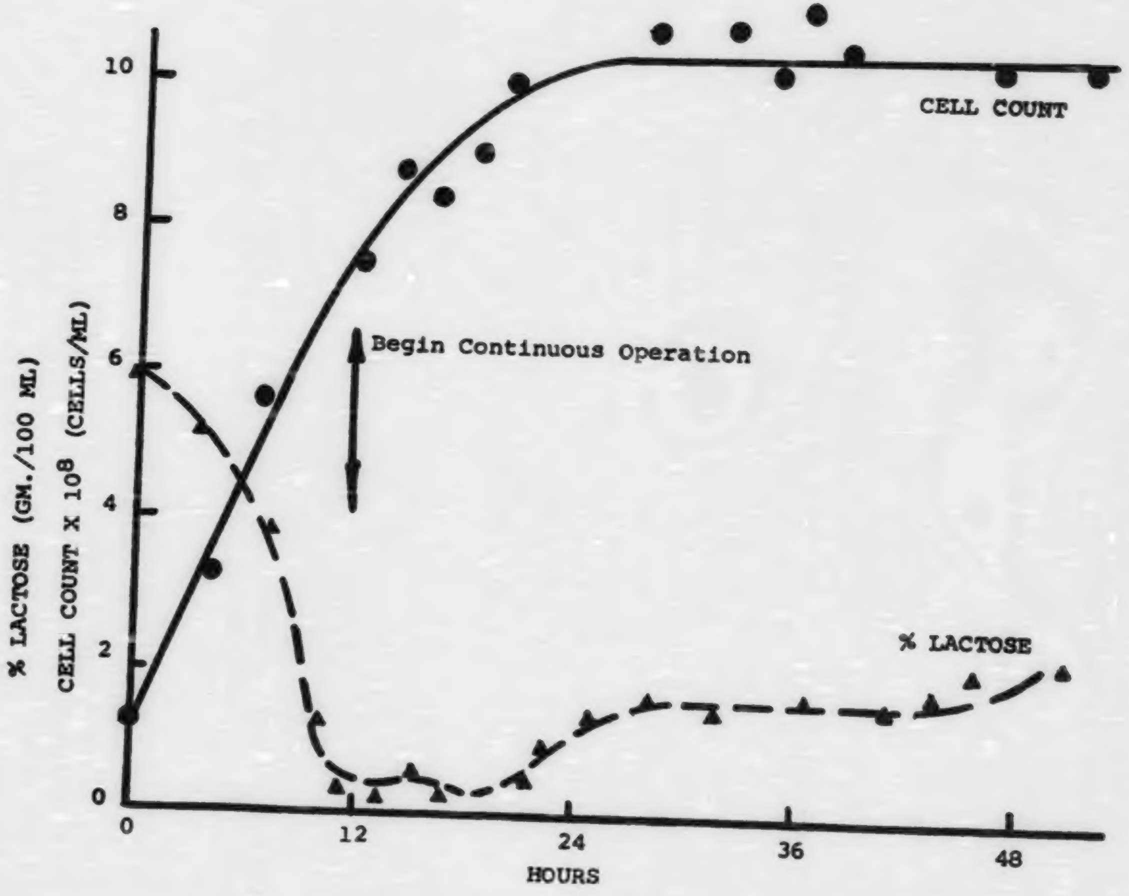

Figure 2. Continuous fermentation - Saccharomyces fragilis.

Table 1. PROXIMATE ANALYSIS OF FERMENTED WHEY PRODUCTS

	Yeast fermented solubles (AMBER YFS), %	Centrifuged yeast (AMBER NUTREX), %
Crude protein	35-50	45-55
Ash	12-20	6-10
Fat	2-3	2
Moisture	3-4	3-4

yeast.[6] These values are 69 percent and 91 percent, respectively, of that of the casein standard. Actual feeding trials are being conducted with larger animals to determine specific values. Such tests with cattle have proved successful and FYS material is being used in a number of commercial feed formulations at the present time.

The quality of the protein produced by this fermentation of whey is further indicated by amino acid analyses. In Table 2 the amino acid composition of this yeast is compared to that of other commercially available yeast used in feeds and foods (Brewers Yeast and Torula Yeast) and to yeast produced by the fermentation of hydrocarbons and ethanol. The standard amino acid FAO profile is also listed for comparison.

During the fermentation, one of the metabolic products formed is ethyl alcohol. By changing conditions of fermentation (operating under almost anaerobic conditions) one can increase the amounts of this material formed. The results of one such run in our 15,000 gallon fermentor is shown in Figure 3. After an initial period of aerobic operation to build up cell concentration, the fermentation broth was "spiked" with additional lactose in the form of condensed whey and the fermentor was run under anaerobic conditions. The lactose was utilized at a continued stready rate. However, the cell population no longer increased, but remained at a constant level. Ethyl alcohol was produced in larger amounts, and calculations indicate that better than 90 percent of the lactose was being converted to this material, the rest being metabolized for cell maintenance. The production of almost 6 percent ethanol in this preliminary experiment indicates the potential production of this important chemical simultaneous with the production of single cell protein. Complicated economic factors, including energy, production and recovery costs, as well as market values of the products, will determine the optimum operation of the process.

In an effort to minimize waste streams from the fermentation operation, a "closed-loop" system was designed. In this process, the concentrated whey was diluted with condensate water derived from the evaporation of the fermentation broths, and this was followed by the fermentation of the whey. Theoretically, this closed-loop could be repeated as often as new whey concentrate was added to the cycle (Figure 4). Since the entire fermentation broth is spray dried, no waste streams are obtained; effectively, therefore, this process has zero effluents. The fermentation results do not differ significantly whether tap water, raw whey or condensate water is used to dilute the incoming condensed whey. The process has been run over extended periods of time, using this closed-loop system, with no apparent build-up of any metabolic toxic product to inhibit the fermentation. In the overall schematic shown in Figure 1, one can see the return of the condensate water to the medium mixing tank.

Table 2. AMINO ACID CONTENT OF VARIOUS SINGLE-CELL PROTEINS COMPARED TO FAO PROFILE

Amino acid	Total protein, %					
	FAO profile	AMBER NUTREX	Brewers yeast	Torula yeast	Brit. Pet. yeast[a]	Amoco yeast[b]
Lysine	4.2	6.9	6.8	8.5	7.5	6.6
Methionine	2.2	1.6	1.5	1.5	1.8	1.4
Valine	4.2	5.4	4.7	5.6	5.8	5.7
Leucine	2.8	7.0	5.8	8.0	7.8	7.1
Isoleucine	4.2	4.0	3.6	6.4	5.3	4.5
Tyrosine	2.8	2.5	2.7	4.3	3.6	3.3
Phenylalanine	2.8	3.4	3.4	5.1	4.3	4.1
Tryptophan	1.4	1.4	1.1	-	1.4	1.2
Histidine	-	2.1	2.1	2.2	2.1	2.1
Threonine	2.8	5.8	5.9	5.1	4.9	5.5

[a] From reference 7.

[b] From reference 8.

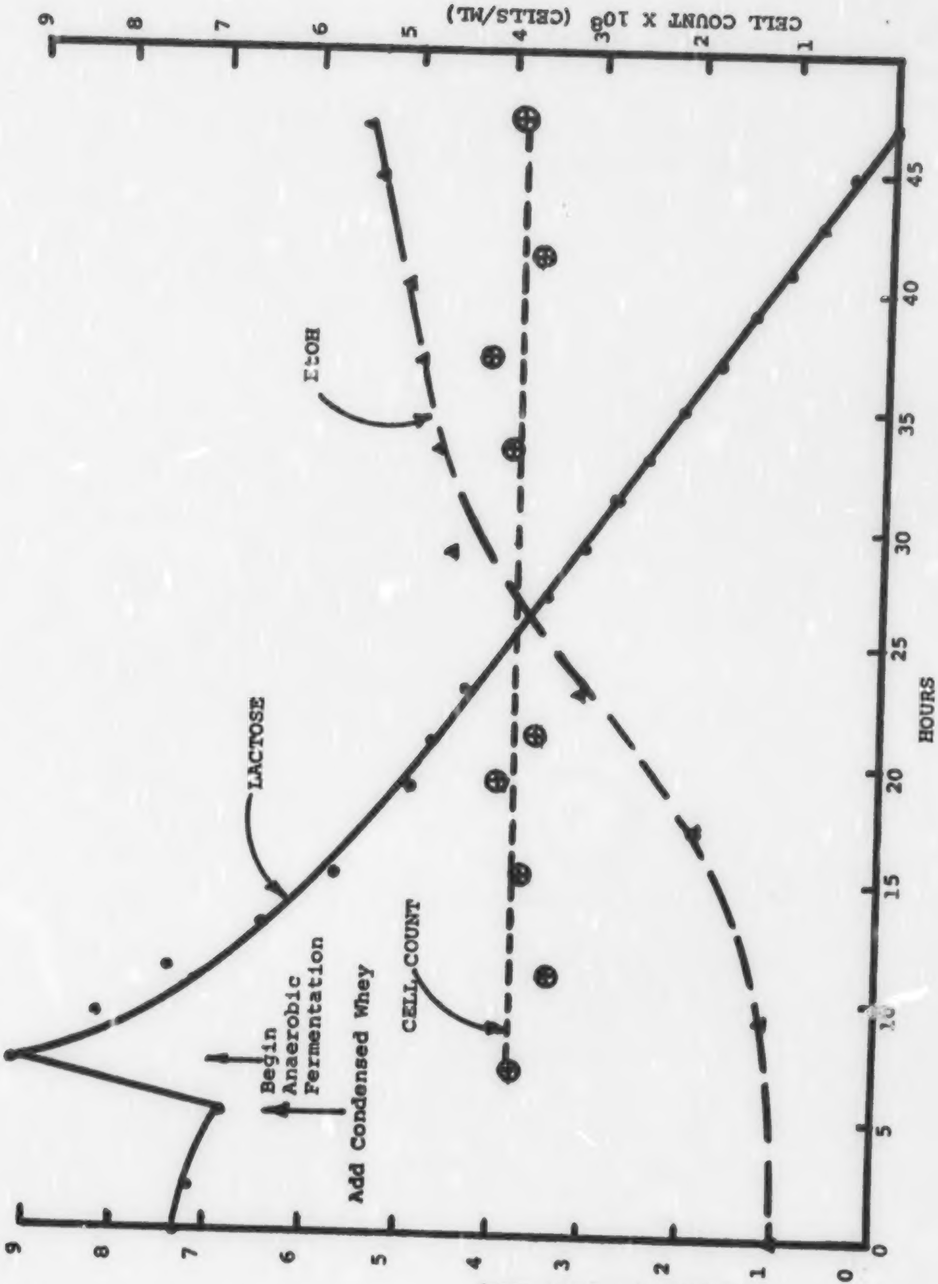

Figure 3. Anaerobic fermentation of *Saccharomyces fragillis.*

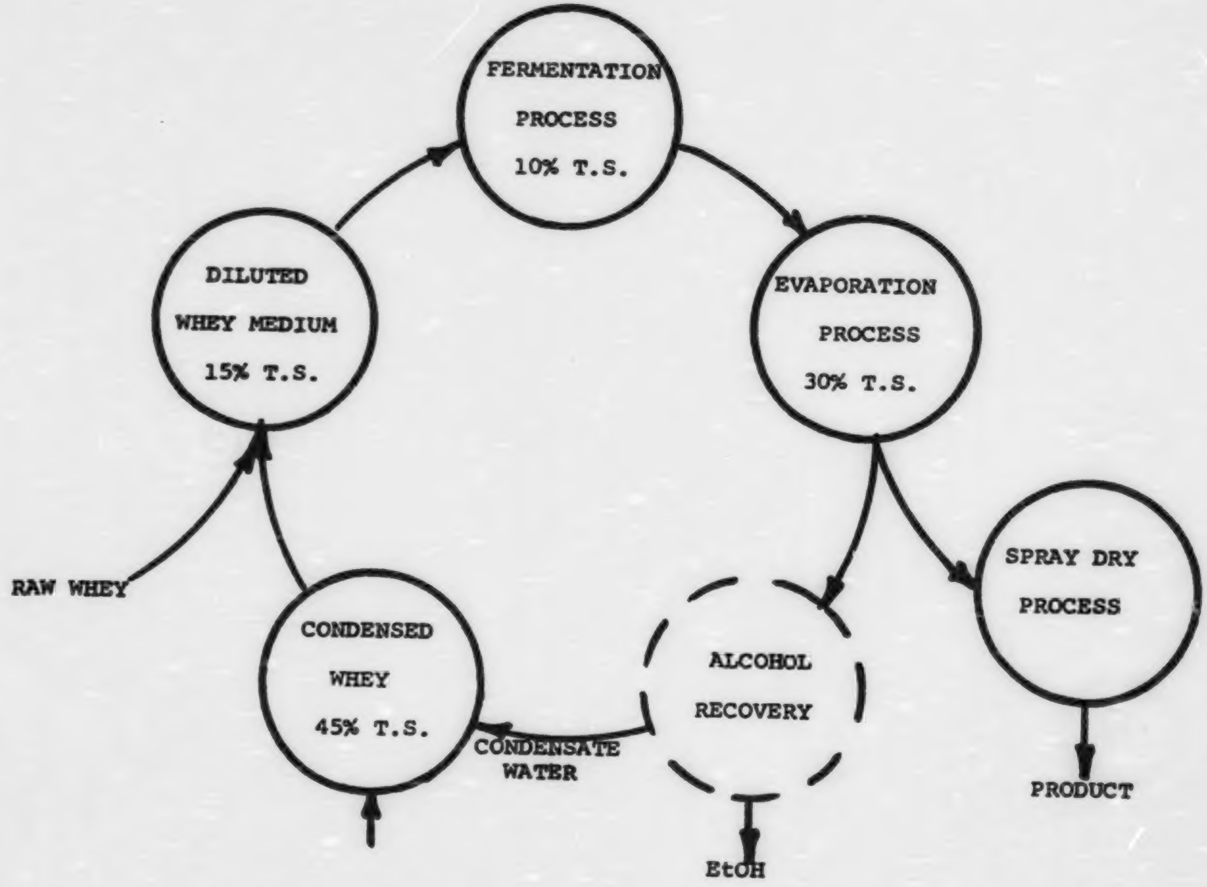
FERMENTATION
PROCESS
10% T.S.
DILUTED
WHEY MEDIUM
15% T.S.
EVAPORATION
PROCESS
30% T.S.
RAW WHEY
SPRAY DRY
PROCESS
CONDENSED
WHEY
45% T.S.
ALCOHOL
RECOVERY
CONDENSATE
WATER
PRODUCT
EtOH

Figure 4. Closed-loop system for minimizing effluents.

ECONOMICS

Preliminary cost calculations of the large scale fermentation verify those made in the extended pilot fermentor operations.[3] The cost of the medium for the fermentation is primarily determined by the cost of whey. While it is possible in the future this material may have a negative value due to the necessary cost of waste treatment of pollution abatement, at the present time, it is realistic to assume that whey may be obtained for the cost of evaporation and/or transportation alone. If this is the case, the medium will cost 3.0 to 5.8 cents per pound of finished product.

The cost of production is also affected by the size of the operation. Labor and other costs decrease on a per pound, finished product basis as the size of the equipment and its degree of automation and sophistication increases. However, as the capacity increases so does the capital investment with its connected charges for depreciation, taxes, insurance and physical facilities. A plant capable of an annual production of 4,000 to 10,000 tons per year would cost in the range of 5 to 15 million dollars, depending on its design, and this is still considered a small fermentation plant. Those being designed for the production of single cell protein from hydrocarbons are in the 100,000 ton annual capacity range. Calculations using present labor, utility and capital investment figures indicate that the feed grade material can be produced in a plant with an annual capacity of 5,000 to 10,000 tons for a total production cost of 12.0 to 15.5 cents per pound. This does not take into account any credit for alcohol recovered which can be of the order of several cents per pound, depending on the conditions for fermentation and the yields obtained. The process looks economically viable assuming a recovery and growth of the presently depressed animal feed industry.

SUMMARY

Saccharomyces fragilis may be grown on acid or sweet whey in a deep tank, aerated fermentor in a continuous manner on a commercial scale. The fermentation itself has many advantages. By operating at a low pH and with a large seed size and high cell count, contamination is not a problem and therefore, sterile or special aseptic equipment or techniques are not necessary. The aeration requirements are not excessive nor is there any problem with foam control. Temperature control, despite the rapid growth rate, is maintained with a low level of cooling water. The medium is simple in composition, and at the concentrations used, the carbohydrate substrate (lactose) is completely soluble. The absence of any potentially toxic substances in the medium simplifies harvesting. The production of a dried whole fermented whey mass (Yeast Fermentation Solubles) eliminates additional processing of waste streams from yeast separators and increases the yield of the fermentation. As a result of the evaporation of the whole fermented mass prior to drying, condensate water is obtained that can be used to dilute incoming condensed whey and thereby operate a completely closed-loop system with no effluents.

By varying the conditions of the fermentation, increased amounts of ethyl alcohol can be produced and recovered but at the expense of cell yield. However, as one expert has recently stated, "Energy considerations could also affect the kind of SCP process. Aeration costs could be important if energy costs continue to rise. Hence, an anaerobic fermentation process, in which both alcohol and SCP feed are produced, could be the process of choice."[9]

Food grade yeast may be produced by harvesting the yeast by centrifugation. Indications are that some of the supernatant streams from this process may be used in certain animal feed fractions.

The protein quality of the finished products is good, although slightly low in the sulfur containing amino acids, as is true of most single cell proteins. Rat feeding tests show no toxicity and feeding experiments with other animals show promising uses in feed rations.

The cost of production is dependent primarily on two factors---the cost of whey and the capital investment. Efficiency demands a plant that is highly automated and instrument controlled and of a size to have an annual capacity of at least 4,000 to 10,000 tons of finished product. This would represent a raw material requirement of the equivalent of 200 to 500 million pounds of raw whey. Therefore, the location of such a facility must be near a large cheese producing area. Such an area should have an excess of whey at little or no cost. The capital investment is large, but must be made to allow the product to compete in the market place.

The present and future shortage of protein has been reported extensively, and many investigators feel one potential solution is the production of single cell protein.[9] Agricultural and industrial waste materials may be used as substrates for such production, thereby decreasing the immense disposal problems they present.[10] Whey is a clean, wholesome, food-grade substance, in excess supply and a potential environmental pollutant. By the process described here, it can be converted to a useful and needed high-protein material, the demand for which is now present and should increase in the future.

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TREATMENT CAPABILITIES OF AN EXTENDED AERATION SYSTEM FOLLOWING ANAEROBIC LAGOONS TREATING MEAT PACKING WASTES

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INTRODUCTION

When the Monfort Packing Company began operation in Greeley, Colorado, they discharged the wastewater from their packing plant into the City of Greeley's sewer system. In 1964, the City of Greeley expanded their waste treatment facilities by adding an activated sludge plant to their trickling filter plant. However, by 1969, these combined waste treatment facilities were organically overloaded and there were serious odor problems. Both the City of Greeley and Monfort Packing Company agreed that the most effective and economical solution would be to remove the packing plant wastewater from the municipal treatment plant and to provide a separate treatment system for the packing plant wastewater.

Following a cost effectiveness analysis of several treatment methods, the decision was reached to use anaerobic lagoons followed by an extended aeration system and two polishing ponds in series with sludge wasting to the anaerobic lagoons. Following the decision on the method of treatment, the next problem was to find an acceptable site for the facilities. Several sites were evaluated before an agreement was finally reached between the City of Greeley and Weld County on the treatment plant site. The planning agencies for the City and the County agreed on the site as well as the City Council and County Commissioners.

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A public hearing was also held before the final decision on the site was reached.

The site that was selected was located 32,500 feet east of the packing plant, adjacent to Lone Tree Creek, approximately one mile north of its confluence with the South Platte River. The effluent from the final polishing pond discharges into Lone Tree Creek.

Because of the ability of the anaerobic lagoons to provide a high degree (80 to 85 percent) of BOD_5 reduction on the packing plant wastes, discussion began covering the possibility of discharging the waste activated sludge from the City of Greeley's activated sludge plant to the anaerobic lagoons as an effective low cost means of sludge disposal. The City's activated sludge plant was located 4,300 feet south of the force main to the anaerobic lagoons and about 32,000 feet west of the anaerobic lagoons. The decision was reached to construct a 6-inch diameter, 4,300 foot long pipeline from the City's activated sludge plant to the 18-inch diameter pipeline from the packing plant to the anaerobic lagoons.

The joint use of the facilities by the City of Greeley and Monfort Packing Company made the project eligible for a grant from the US Environmental Protection Agency (EPA).

The force main from the packing plant to the treatment plant site including the sludge line from the City's activated sludge line to the force main, cost $462,500, while the treatment facilities cost $581,300. The project was bid in April of 1972, and construction was completed in late 1973. The total grant eligible cost was $983,000 and the EPA grant on the project was $472,890, leaving $570,910 to be financed by the City of Greeley and repaid by Monfort Packing Company as a part of their sewer service charge.

DESIGN BASIS FOR WASTE TREATMENT SYSTEM

Design Loadings

The following are the design loadings for the waste treatment facilities showing the breakdown between Monfort Packing Company and the City of Greeley.

	Monfort Packing Co.	City	Total
Flow, mgd	2.67	0.10	2.77
BOD_5, pounds per day	30,000	5,000	35,000
Suspended solids (SS), pounds per day	26,500	9,000	35,000

Flow Schematic

Figure 1 is a diagram showing the flow schematic for the waste treatment facilities.

The BOD_5 removals contemplated by the complete treatment system were as follows:

	Design Removals	Annual Average Removals
Anaerobic Lagoons, BOD_5	75%	80.3%
Extended aeration system	91.5%	82.0%*
Combined removal-anaerobic A.S. system	97.9%	97.0%*
Polishing lagoons, BOD_5	50%	60%
Treatment system removals (BOD_5)	98.9%	98.2%
Treatment system removals (SS)	98.9%	94.4%
BOD_5 remaining in effluent, pounds per day	375	188
SS remaining in effluent, pounds per day	375	395

*July to February

Design Basis for Extended Aeration System

The design of the extended aeration system following the anaerobic lagoons assumed the following waste characteristics of the effluent from the anaerobic lagoons.

Flow	2.77 mgd
BOD_5	8,750 pounds per day (380 milligrams per liter)
Suspended solids	5,770 pounds per day (250 milligrams per liter)
Percent of volatile solids	74 percent
Inert volatile suspended solids	50 milligrams per liter
Average temperature	20 degrees C (75 degrees F)
Aeration time	1.33 days

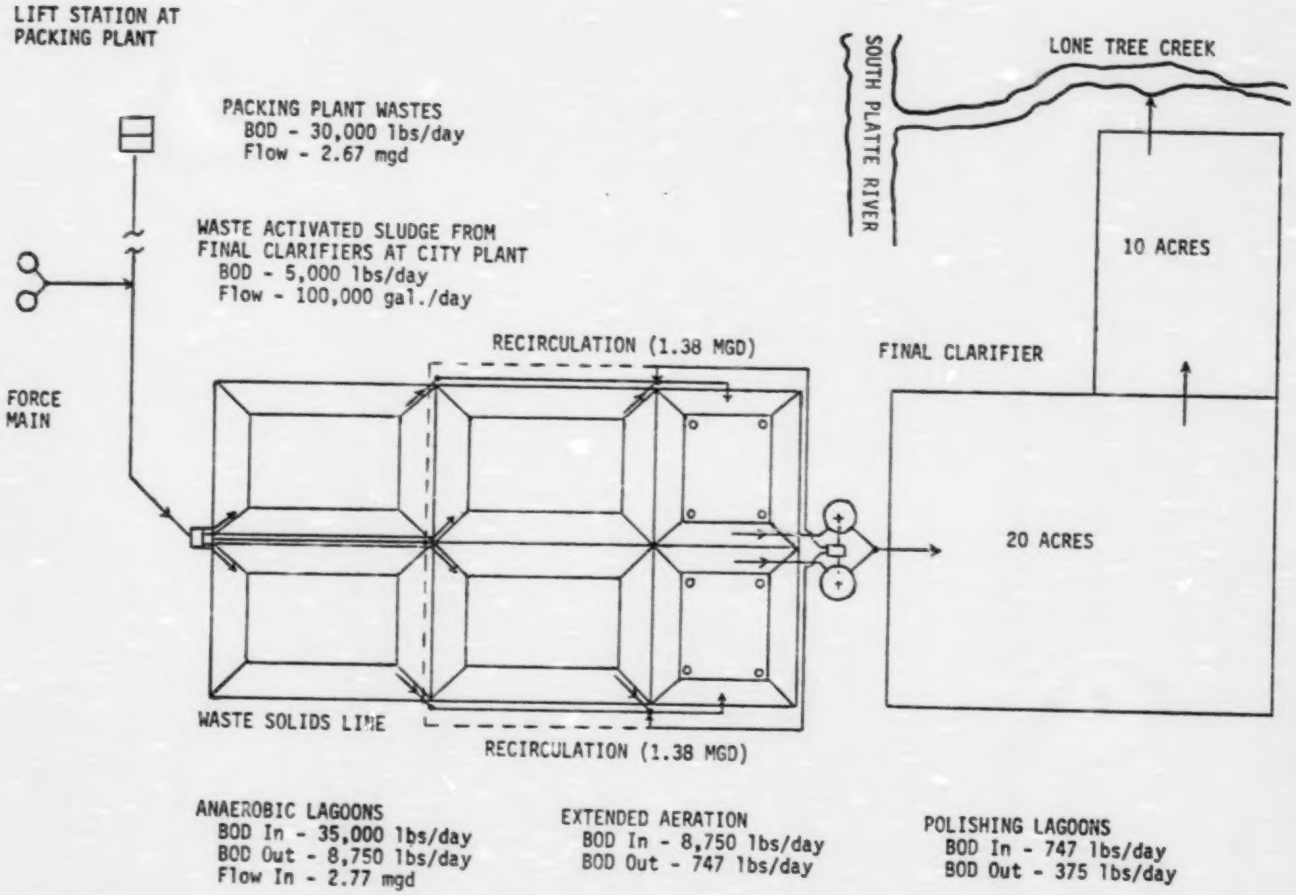
LIFT STATION AT PACKING PLANT
PACKING PLANT WASTES
BOD - 30,000 lbs/day
Flow - 2.67 mgd
WASTE ACTIVATED SLUDGE FROM FINAL CLARIFIERS AT CITY PLANT
BOD - 5,000 lbs/day
Flow - 100,000 gal./day
FORCE MAIN
RECIRCULATION (1.38 MGD)
WASTE SOLIDS LINE
RECIRCULATION (1.38 MGD)
SOUTH PLATTE RIVER
LONE TREE CREEK
10 ACRES
FINAL CLARIFIER
20 ACRES
ANAEROBIC LAGOONS
BOD In - 35,000 lbs/day
BOD Out - 8,750 lbs/day
Flow In - 2.77 mgd
EXTENDED AERATION
BOD In - 8,750 lbs/day
BOD Out - 747 lbs/day
POLISHING LAGOONS
BOD In - 747 lbs/day
BOD Out - 375 lbs/day

Figure 1. Flow schematic of waste treatment facilities - Greeley, Colorado.

Elevation of site	4,650 feet
Beta factor	0.80
Alpha factor	0.9
Oxygen transfer-std. condition	2.9# $^{O}2$/hp-hr
Oxygen transfer-field cond.	1.48# $^{O}2$/hp-hr
Required horsepower	320 horsepower
Aeration equipment	8-40 horsepower floating aerators
Mixed liquor suspended solids (MLSS)	3,000 milligrams per liter
Waste sludge	To anaerobic lagoons
Return sludge rate	100 percent
Dissolved oxygen in aeration basin	1.0 milligrams per liter
Number of aeration basins	2
Aeration basin depth	9 feet
Number of clarifiers and diameter	2 at 55 feet (suction type)
Clarifier overflow rate	580 gallons per feet^2 per day
Clarifier sidewater depth	10 feet
Calculated treatment effluent	91.5 percent
Effluent BOD$_5$	32 milligrams per liter

The formulas used for calculating the required detention time, mixed liquor suspended solids in the aeration basin and oxygen uptake as well as the predicted BOD$_5$ in the effluent from the final clarifier were those developed by Dr. Ross McKinney for complete mix activated sludge systems. The constants used in the formulas were the same as those for domestic wastes.

Since nitrification of the effluent was not required for the treatment system, no additional horsepower was included in the aeration basins for this purpose.

OPERATING RESULTS

General

At the time the construction of the project was completed in the late fall of 1973, the new water supply from the City of Greeley to Monfort Packing Company had not been completed. The water supply at the packing plant contained 700 to 800 milligrams per liter of sulfates which was from wells while the City water supply contained only 10 milligrams per liter of sulfates. However, because of odor problems at the City of Greeley's waste treatment plant, the decision was made after consultation between the City, State and Federal officials to start the system before the water supply was changed over. As would be anticipated, odor problems occured at the anaerobic lagoons. It wasn't until the fall of 1974 that the new water supply was extended to the packing plant. The odor problems diminished cnsiderably; although it has taken some time to purge the entire lagoon system of the sulfates.

The present water supply comes from reservoirs capturing snow melt and runoff from the Rocky Mountains west of Greeley, Colorado and shows a sulfate concentration of less than 10 milligrams per liter. However, the total alkalinity is also quite low (28 milligrams per liter).

Anaerobic Lagoons

The anaerobic lagoons were designed at a loading rate of 12 pounds of BOD_5 per 1,000 cubic feet with an assumed treatment efficiency of 75 percent. The force main from the packing plant to the anaerobic lagoons is approximately 32,000 feet in length and there was some concern that the temperature drop in the force main may reduce the treatment efficiency of the anaerobic lagoons. This later proved not to be a problem.

Figure 2 shows the concentration of BOD_5 in the influent and effluent from the anaerobic lagoons as well as the percent reduction of BOD_5. The treatment efficiency varied from a low of 60 percent in April and a high of 88 percent in September, with an annual average of 80.3 percent. The BOD_5 concentration in the effluent ranged from 157 to 377 milligrams per liter, with an annual average of 295. The assumed anaerobic lagoon BOD_5 effluent concentration was 280 milligrams per liter.

Figure 3 shows the concentration of suspended solids for the anaerobic lagoon influent and effluent along with the percent reduction. The assumed anaerobic lagoon concentration of suspended solids was 250 milligrams per liter.

Extended Aeration System

Figure 4 shows the concentration of BOD_5 for the extended aeration system influent and effluent along with the percent reduction. After the system had stabilized by July 1, 1974, the BOD_5 concentration in the effluent varied from a low of 21 milligrams per liter in September to a high of 67 milligrams per liter in January. The percent reduction of BOD_5 varied from 76 percent to 86 percent and averaged 82 percent.

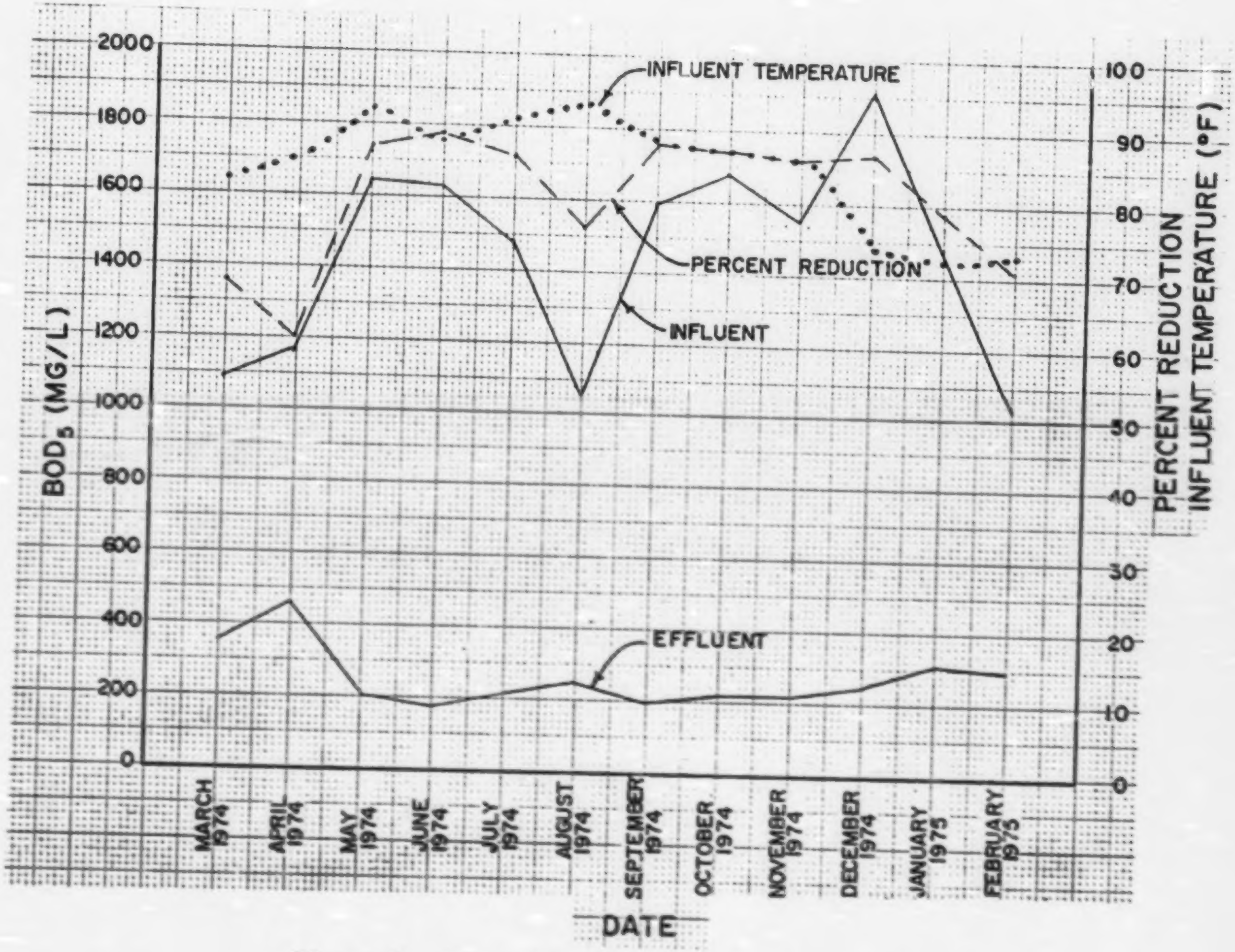

Figure 2. Anaerobic lagoon performance - BOD_5.
Waste treatment facilities - Greeley, Colorado.

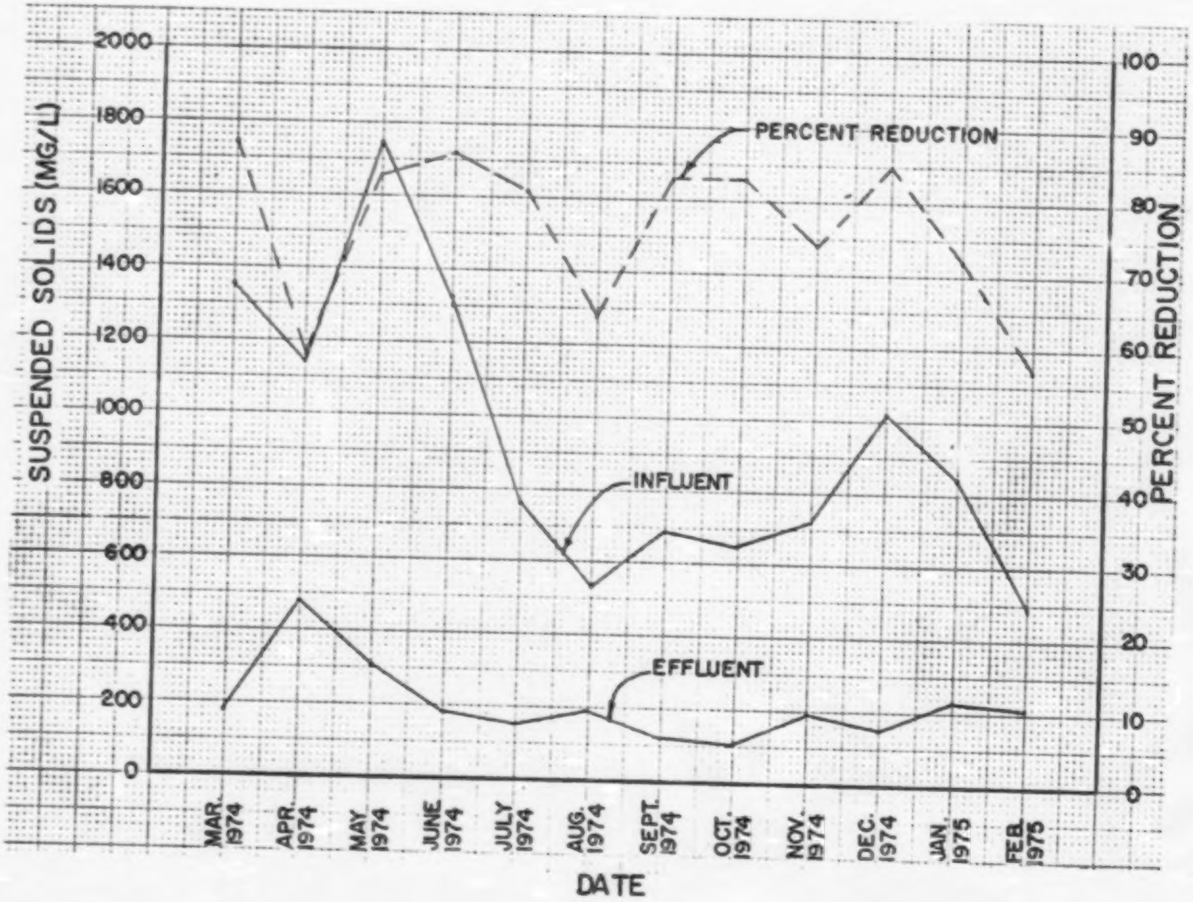

Figure 3. Anaerobic lagoon performance - suspended solids.
Waste treatment facilities - Greeley, Colorado.

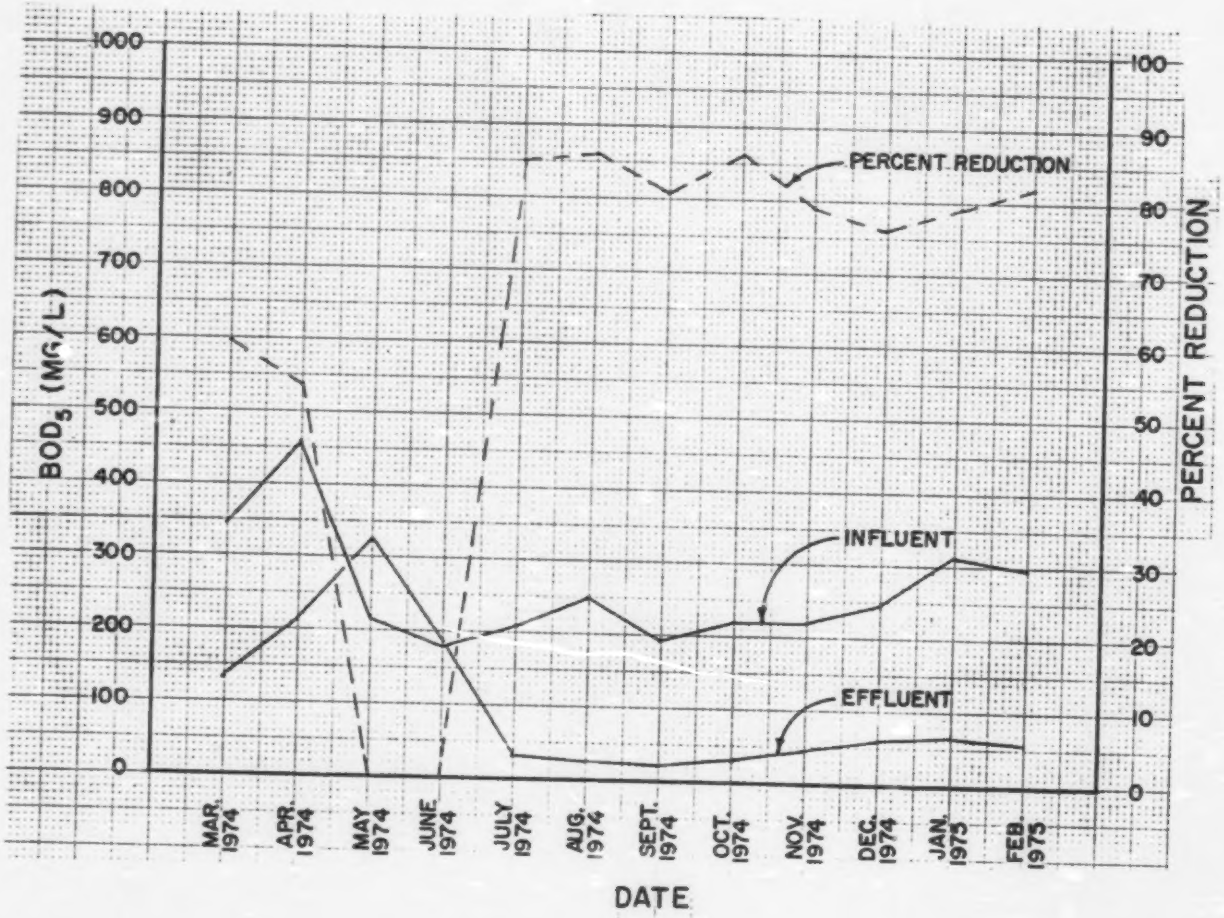

Figure 4. Extended aeration performance - BOD$_5$.
Waste treatment facilities - Greeley, Colorado.

Figure 5 shows the concentration of suspended solids for the extended aeration system influent and effluent along with the percent reduction. After the system had stabilized by July 1, 1974, the suspended solids concentration in the effluent varied from a low of 20 milligrams per liter in October to a high of 137 milligrams per liter in February. The percent reduction of suspended solids varied from 35 percent to 82 percent and averaged 62 percent.

The design BOD_5 reduction for the extended aeration system was 91.5 percent with the overall percent reduction for the anaerobic lagoon and extended aeration system of 97.9 percent. This compared with the percent reduction for the extended aeration system of 82.0 percent for the period of July 1974 to February 1975, while the overall percent reduction for the anaerobic lagoons and extended aeration averaged 97.0 percent for the same period. The low treatment efficiencies in the months of May and June were due to low MLSS concentrations in the aeration basin of 495 to 1,145 milligrams per liter. This occurred due to mechanical problems with the surface aerators. The dissolved oxygen was zero for half of the readings.

The BOD_5 and suspended solids in the effluent from the polishing lagoon for each of the months of record are as follows (see Figures 6 and 7):

	BOD_5, pounds per day	Suspended solids
March	112	550
April	292	628
May	380	770
June	134	255
July	133	117
August	167	293
September	134	255
October	120	230
November	297	691
December	194	394
January	136	340
February	188	395
Average	188	395

Special Study in February 1975

We anticipated that the most difficult time for the extended aeration system would be the winter period. Consequently, the month of February was selected for a special study in which daily readings were taken to determine the following parameters:

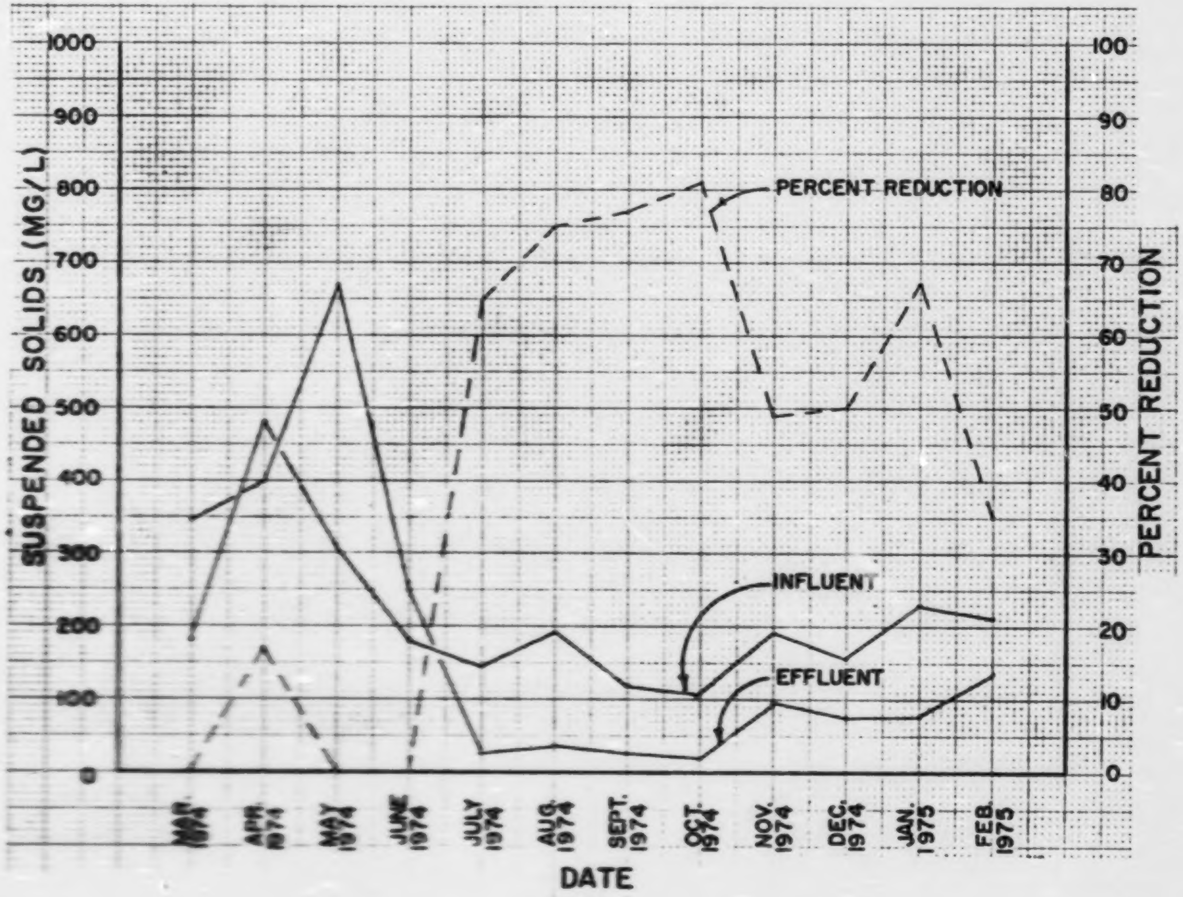

Figure 5. Extended aeration performance - suspended solids. Waste treatment facilities - Greeley, Colorado.

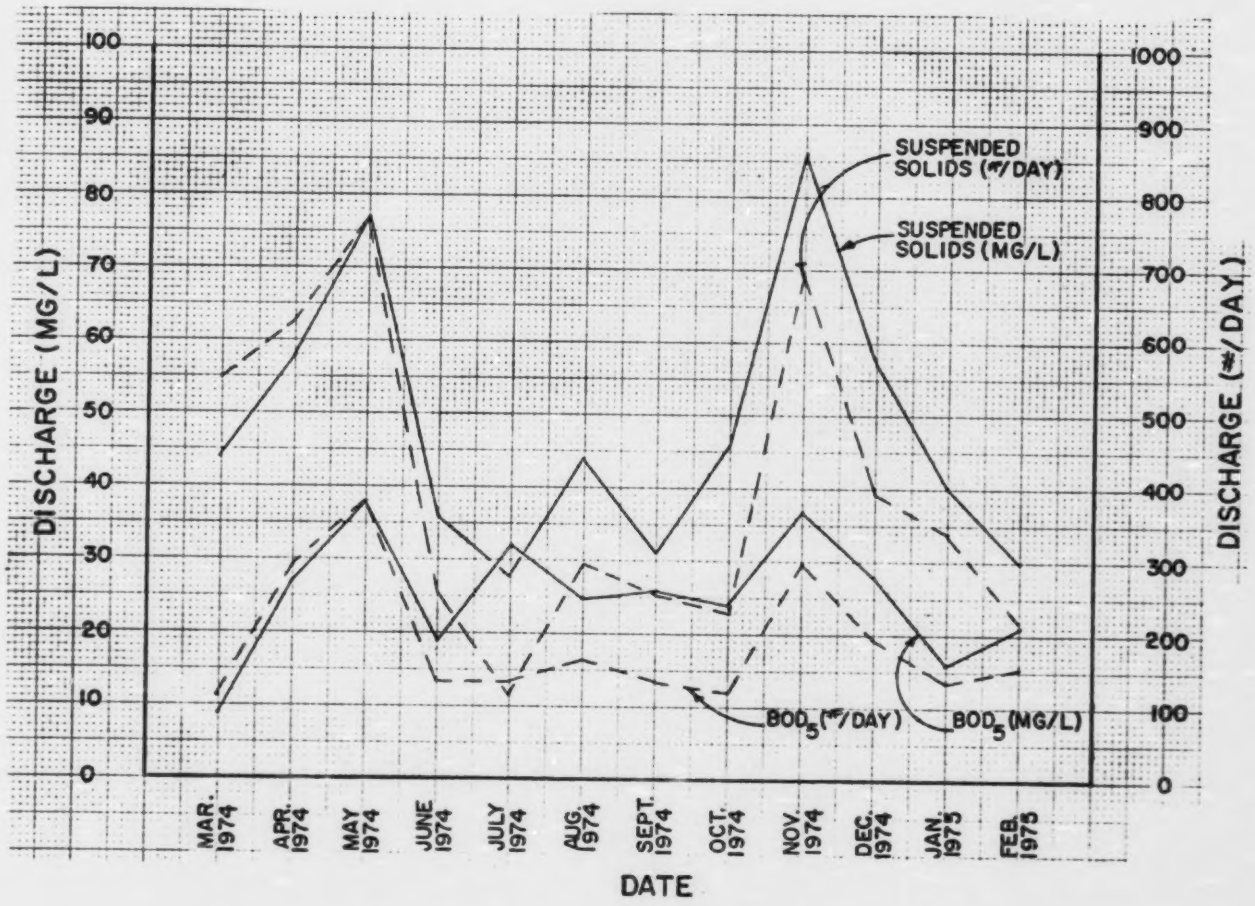

Figure 6. Polishing pond effluent.
Waste treatment facilities - Greeley, Colorado.

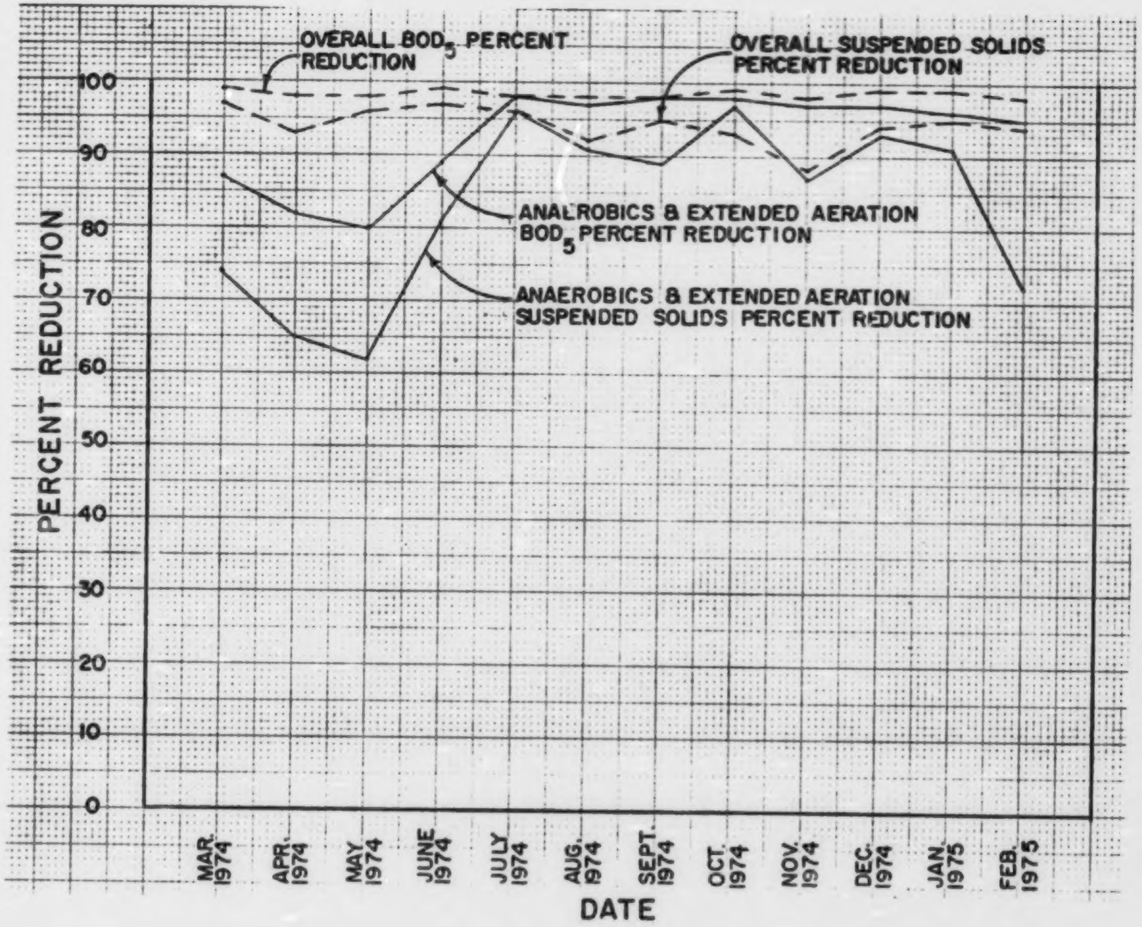

Figure 7. BOD$_5$ and suspended solids reductions.
Waste treatment facilities - Greeley, Colorado.

1. MLSS in Aeration Basin,
2. MLVSS in Aeration Basin,
3. Pounds MLSS per pounds BOD_5,
4. Return Solids, milligrams per liter,
5. Return Solids as a percent of Solids in Basin,
6. Sludge Volume Index,
7. Influent Temperature
8. Influent and Effluent BOD_5, SS, and
9. Percent Reduction, BOD_5, SS.

Figure 8 shows the data collected during February including monthly average values. The MLSS generally varied from 2,550 milligrams per liter to 3,625 milligrams per liter with an average of 3,036 milligrams per liter. The pounds BOD_5 per pound MLSS is at the low end of the activated sludge range varying from 0.010 to 0.058 and averaging 0.025. The influent BOD_5 averaged 295 milligrams per liter and the average BOD reduction in February for the extended aeration system was 83.9 percent. The influent suspended solids concentration averaged 208 milligrams per liter and the average suspended solids reduction was 79.7 percent during February.

The effluent BOD_5 from the final polishing pond varied from 15 to 35 milligrams per liter and averaged 21 milligrams per liter. The suspended solids in the final pond varied from 18 to 40 milligrams per liter and averaged 30 milligrams per liter. During the month of February, there were only two days in which any sludge was wasted, that being on the 20th and 28th of February when 3,216 pounds and 3,485 pounds, respectively, were wasted. The extended aeration system is operating well within the endogenous respiration phase and thus the solids that must be wasted is minimal. However, the monthly data shows the MLSS were increasing from 2,940 milligrams per liter to 3,625 milligrams per liter.

The results of the winter operation of the extended aeration system show the system to be very lightly loaded with an average ratio of pounds BOD per pound MLSS of only 0.025. With an actual detention time of 2.5 to 3.5 days, the surface aerators cause a considerable drop in temperature of the wastewater in the winter pierod with a corresponding drop in treatment efficiency. Fortunately, the polishing pond levels out the fluctuation with an average BOD_5 of 21 milligrams per liter and an average suspended solids of 30 milligrams per liter for the month of February.

The dissolved oxygen in the aeration basin was considerably above the desired level of 2.0 milligrams per liter with values ranging from 7.7 to 10.0 milligrams per liter. The aerators have been placed on a time clock to cycle their operation to save on horsepower since the dissolved oxygen level above 2.0 milligrams per liter is of no real

Date	Anaerobic Effluent		Final Clarifier Effluent				Pond Effluent				Aeration Basin				
FEB'75	BOD_5	S.S.	BOD_5	% Red	S.S.	% Red	BOD_5	% Red	S.S.	% Red	Ana. Eff. Temp.°F	MLSS	MLVSS	#BOD/ #MLSS	Sludge Volume Index
2	251	172	47	81.3	52	69.8	22	53.2	32	38.5	-	2940	2180	-	139
3	315	255	49	84.4	42	83.5	29	40.8	36	14.3	56	2780	2070	.021	137
4	192	130	45	76.6	54	58.5	32	28.9	26	51.9	64	2750	2040	.015	149
5	220	107	60	72.7	52	51.4	18	70.0	32	38.5	66	2815	2090	.015	138
6	219	195	-*	-	-*	-	19	-	38	-	72	-	-	-	123
8	238	173	59	75.2	64	63.0	21	64.4	40	37.5	68	2550	1920	.026	149
9	157	153	30	80.9	56	63.4	13	56.7	32	42.9	66	2876	2680	-	129
10	357	163	46	87.1	48	70.6	26	43.5	24	50.0	66	2790	2050	.022	127
11	300	188	-	-	70	62.8	35	-	32	54.3	74	2720	2040	.030	144
12	262	153	35	86.6	38	75.2	18	48.6	22	42.1	74	2770	2075	.023	144
13	287	178	40	86.1	62	65.2	21	47.5	34	45.2	78	2825	2110	.025	246
14	298	220	29	90.3	21	90.5	18	37.9	30	-	76	2935	2195	.025	186
15	307	240	28	90.9	13	94.6	19	32.1	24	-	74	3000	2295	.024	176
16	349	260	13	96.3	14	94.6	27	-	34	-	72	3170	2375	.010	224
18	278	130	32	88.5	24	81.5	20	37.4	33	-	74	3080	2314	.026	237
19	293	224	36	87.7	20	91.1	27	25.0	38	-	77	2984	2333	.028	209
20	360	195	49	86.4	15	92.3	24	51.0	28	-	77	3115	2315	.030	274
21	343	240	48	86.0	40	83.3	16	66.7	22	45.0	74	3010	2240	.058	272
22	303	220	32	89.4	26	88.2	15	53.1	18	30.8	72	3070	2380	.023	256
23	352	370	68	80.7	53	85.7	21	69.1	36	32.1	71	3365	2540	.016	250
24	304	210	58	80.9	31	85.2	20	65.5	26	16.1	76	3425	2555	.019	192
25	330	205	60	81.8	22	89.3	17	71.7	32	-	81	3310	2500	.029	263
26	354	220	-	-	24	89.1	20	-	30	-	79	3500	2650	.028	239
27	377	300	76	80	26	91.3	19	75.0	29	-	80	3465	2630	.028	231
28	323	305	78	76	22	92.8	19	75.6	27	-	80	3625	2705	.023	245
AVG.	295	208	46	83.9	37	79.7	21	54.9	30	38.5	72.8	3036	2303	0.025	195.2

* FLOW SURGE OF 100% CAUSED BOD TO RISE TO 194 MG/L AND S.S. TO 600 MG/L.

MLSS - MIXED LIQUOR SUSPENDED SOLIDS

MLVSS - MIXED LIQUOR VOLATILE SUSPENDED SOLIDS

Figure 8. Extended aeration system, special study - February 1975.
Waste treatment facilities - Greeley, Colorado.

value. Consideration has also been given to closing down one-half of the system.

Nitrification

As indicated previously, no horsepower was provided for nitrification of the ammonia nitrogen in the effluent from the anaerobic lagoons. However, since the extended aeration system was operating below its design loading, there was sufficient oxygen available for nitrification. The following preliminary nitrogen determinations were made using a Hach test kit.

Location	Date	Milligrams per liter		
		NH_3-N	NO_3	NO_2
Final Clarifier	8-9-74	5	50	7
Final Pond	8-9-74	17	22	6
Final Clarifier	9-2-74	1	23	-
Final Pond	9-2-74	2	14	-

On November 11, 1974, a complete nitrogen balance was made using Standard Methods, with the following results noted:

Location	Milligrams per liter			
	TKN	NH_3-N	NO_3	NO_2
Anaerobic Effluent	60.4	48.6	0.01	0
Final Clarifier Effluent	5.7	3.3	57.7	3.4
Final Pond	9.5	2.1	13.0	1.7

On December 26, 1974, following colder weather and the change to a low alkalinity water supply (total alkalinity---28 milligrams per liter), the following results were obtained: (Adequate dissolved oxygen was available in the aeration basin.)

Location	Milligrams per liter			
	TKN	NH_3-N	NO_3	NO_2
Anaerobic Effluent	58	56	0	0
Final Clarifier Effluent	43.6	43.4	4.8	0.8

Because of the continued cold weather, no further nitrogen determinations were made of the final clarifier effluent in January and February of 1975. However, the following nitrogen determinations were obtained on the final pond effluent.

Date	Milligrams per liter		
	NH_3-N	NO_3	NO_2
1-15-75	45	31	7.0
1-16-75	35	29	6.5
1-20-75	40	26	6.0
1-21-75	30	26	6.0
1-24-75	40	20	4.5
1-30-75	44	13	3.0
1-31-75	45	15	3.5
2-04-75	45	10	2.3
2-08-75	44	11	2.5
2-11-75	45	10	2.2
2-13-75	50	11	2.5
2-15-75	48	7.7	1.8
1-18-75	50	7	1.6
2-19-75	53	7	1.6
2-21-75	55	7	1.6

On March 24, 1975, after the weather had warmed somewhat, another nitrogen balance was taken. The temperature of the anaerobic effluent was 15 degrees C and the final clarifier effluent temperature was 11.5 degrees C. The dissolved oxygen in the aeration basin was well above 2.0 milligrams per liter.

Location	Milligrams per liter			
	TKN	NH_3-N	NO_3	NO_2
Anaerobic Effluent	93	81	0.05	0
Final Clarifier Effluent	48	47	29.6	4.9

While the temperature of 11.5 degrees C is less than optimum, there should have been a higher degree of nitrification than was achieved. The answer appears to be that the ability of the extended aeration system to nitrify is limited by the low alkalinity of the raw water supply.

Fecal Coliform Reductions

The Water Quality Control Division of the Colorado Department of Health tested the effluent for fecal coliform during the months of November and December 1974 and January 1975, with the following results:

Months	Fecal Coliform MPN per 100 milliliters
November 1974	<100
December 1974	< 22
January 1975	<100

The average detention time in the polishing ponds was approximately 45 to 60 days.

SUMMARY

An extended aeration system following an anaerobic lagoon does not behave a great deal differently than an extended aeration system treating domestic wastes, with the exception that consideration must be given to the oxygen demand of sulfides in the anaerobic lagoon effluent. Further, if nitrification of the ammonia nitrogen is required, adequate oxygen must be included to nitrify the NH_3-N. In addition, the alkalinity of the water becomes critical for a nitrification system.

Since 7.0 milligrams per liter of alkalinity as $CaCO_3$ are required for each milligram per liter of NO_3 formed, there is an insufficient quantity of alkalinity in the water to nitrify the NH_3-N in the anaerobic effluent. If and when nitrification is required, the addition of some form of alkalinity will be necessary.

Also, if nitrification is to be a requirement in a future extended aeration system, the aeration basins would have to be designed to conserve heat by making them deeper and by changing from a surface aeration system to either static tube aerators or a diffused aeration system. In our opinion, this type of aeration system would be required to minimize the heat loss that occurs from surface type aerators.

As an example, if the temperature of the influent to the extended aeration system were 75 degrees F and the air temperature is 0 degrees F with a 20 mile per hour wind, with a sidewater depth of 15 feet, with a detention time of 24 hours, and with surface aerators, the water temperature in the aeration basin would drop to 6 degrees C (43 degrees F) or less.

The study showed that a treatment system consisting of anaerobic lagoons followad by an extended aeration system is capable of accomplishing BOD_5 reductions in the range of 95 to 98 percent, with an average of 97 percent. The corresponding suspended solids reductions ranged from 72 to 97 percent, with an average of 89.5 percent. The extended aeration system itself accomplished BOD_5 reductions of 76 to 86 percent with an average of 82 percent. The corresponding values for suspended solids showed a range of 35 to 81 percent with an average of 62 percent. The overall treatment system efficiency for BOD_5 including the polishing lagoons varied from 97.7 to 99.2 percent, with an average of 98.2 percent. The corresponding values for suspended solids ranged from 88.0 percent (influent suspended solids only 719 milligrams per liter) to 97.3 percent and averaged 94.4 percent.

Odors from the anaerobic lagoon continue to be a problem due in part to the untimely start up of the lagoons, while the high sulfate concentrations existed in the water supply. The system still shows 80 milligrams per liter of sulfates in the effluent of the polishing pond, even though the raw water only has 10 milligrams per liter of sulfates.

During the special study during the month of February, the pounds BOD_5 and suspended solids per 1,000 pounds live weight kill (LWK) for the extended aeration system and the complete treatment system were as follows: (The values for February 6 and 7 were not included due to an operational problem with loss of MLSS in aeration basin.)

	Extended Aeration Effluent	Polishing Pond Effluent
BOD_5, pounds per 1,000 pounds LWK	0.144	0.106
Suspended Solids, pounds per 1,000 pounds LWK	0.120	0.152

For the design of an extended aeration system following anaerobic lagoons, consideration should be given to a polishing pond which serves as a buffer to even out the occasional and almost inavoidable upsets that can and do occur in an extended aeration system. The polishing pond also serves to reduce the fecal coliform concentrations to less than 400 MPN per 100 milliliters.

A PROGRESS REPORT ON A SYSTEMS APPROACH TO EFFLUENT ABATEMENT IN HAWAII

Richard T. Webb*

INTRODUCTION

The major concepts for a waste water management system in Hawaii were first described at the Fourth National Symposium on Food Processing Wastes in 1973. This report will outline some of the successes and failures resulting from the implementation of these concepts on a full-scale production basis.

Quality Measurement of Harvesting Operations

Early experiments to determine the quality-effectiveness of new harvesting methods and machinery with respect to minimal soil pick-up indicated that traditional harvesting test methods lacked critically important objectivity. It became necessary to devise methods which avoided the "test bias" or "halo effect" which occurs when a test is run on an innovative production operation.

Prototype harvesting machinery had shown in early tests a soil pick-up of about 5 percent of the weight of cane compared with 15 percent or more with the conventional methods. New machines based on the prototype seldom achieved the required 5 percent level during production runs and questions arose as to the actual amount of entrained soil in the harvested cane. Test data for the new harvesting method had been manually determined by collecting several samples of a few hundred pounds each and making a separation of soil, cane and leaves. The results were erratic and contradictory and varied with rainfall and trash quantities.

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A revised method was developed which has several advantages:

1. Sampling could become routine regradless of the type of test and analysis required, thus reducing test bias;
2. Moisture effects could be eliminated, thereby minimizing the effect of rainfall on the test data; and
3. The effect of variations in the quantity of leafy trash could be minimized, although a minor systematic error remained, for which compensation was made.

The new method consisted of subsampling test cores of harvested material which were routinely taken for the purpose of determining the amount of sugar to be allocated to each harvest field. The core-sampling technique (see Figures 1 through 4) had been approved several years earlier by the US Department of Agriculture for use in the Hawaiian Sugar Industry and is statistically accurate.

The test-core subsamples were analyzed for fiber and were then ashed at 500 degrees C for 24 hours for soil determination, expressed as bone dry ash. A correction of 0.4 percent for ash due organic matter (cane fiber) was then made to bring the samples to the same relative basis. This introduced a small error considered to be of lesser magnitude than the sampling and analytical error.

It is known that ashing at 500 degrees C causes a loss of water of hydration of the soils in the area, which loss is about 27 percent (Table 1). However, field data were collected on the basis of ashed soil in order to provide a simple analytical procedure applicable to all samples under all conditions and which eliminated the possibility of errors of sampling and analysis that often occur in routine moisture analyses of field cane. Of primary importance was the requirement for a sampling and analytical method which provided objective low-cost high-volume measurement data for relative quality of performance determinations between different harvesting methods under all conditions of weather and terrain. These data, by correcting for loss of water of hydration upon ignition, are also being used for estimating the soil disposal tonnages and the necessary size of wastewater treatment facilities.

The quality measurements sought are intended to provide a basis for selection of the optimum cane harvesting system for the Hilo Coast of Hawaii as described at the Fourth Symposium. The new system, including transportation and discharging facilities at the factory, is called "Cane Materials Handling", hereafter abbreviated to CMH. The old system is called "conventional" or "long cane".

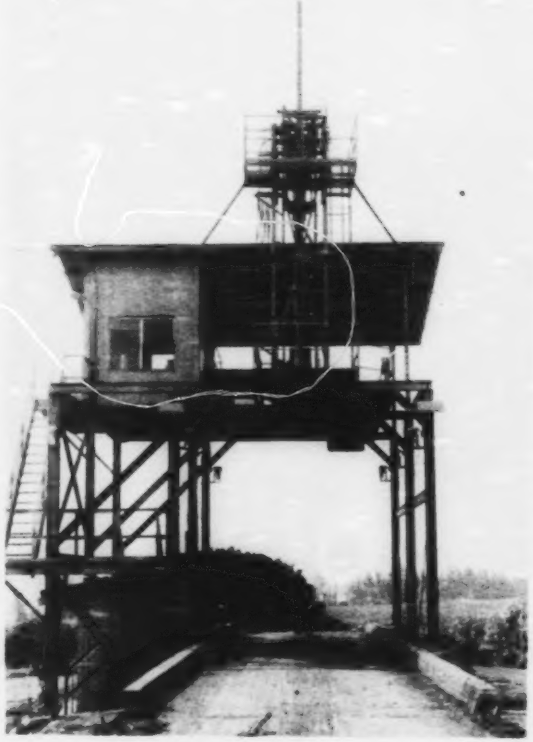


Figure 1. Core sampling station.

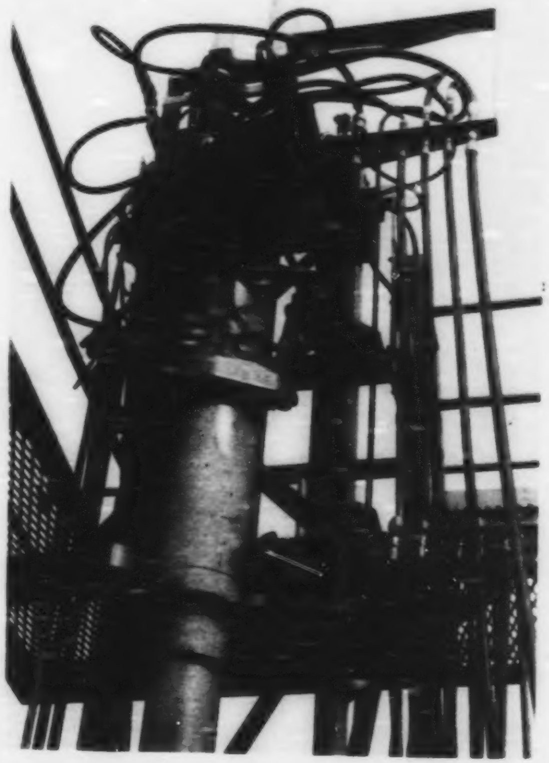


Figure 2. Hydraulic drive - tube coring device.

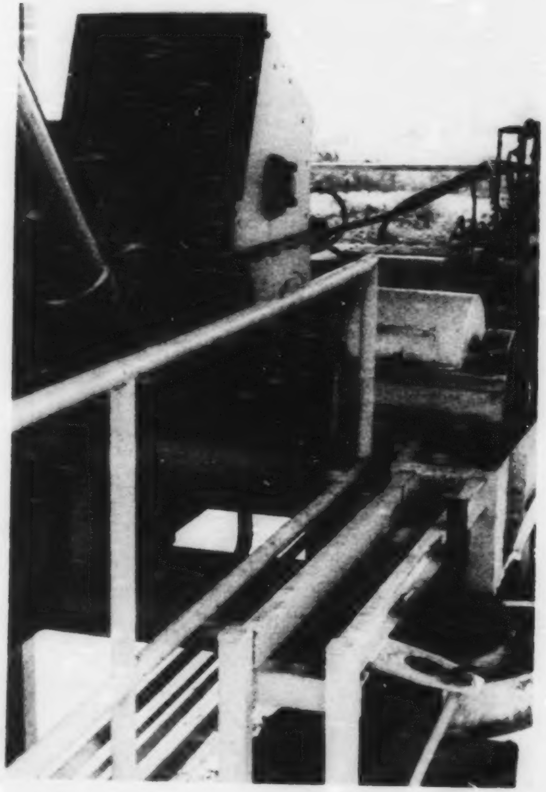


Figure 3. Core tube approaching sub-sampling device.

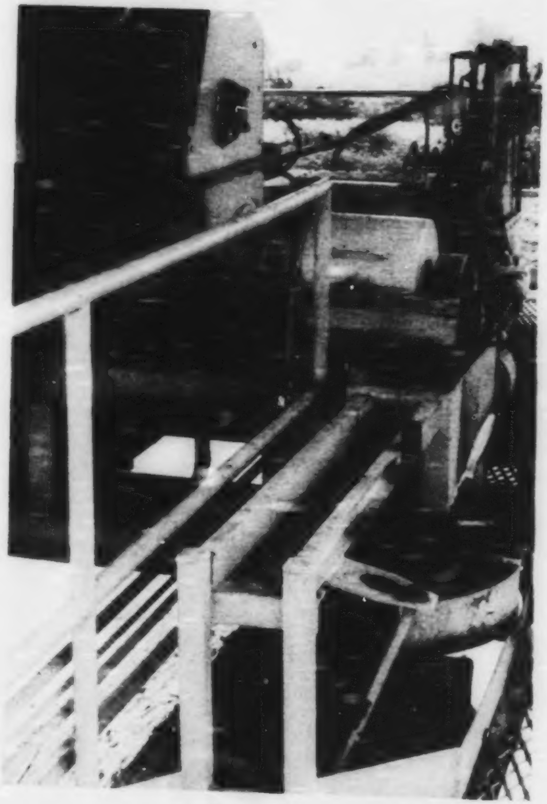


Figure 4. Sub-sampler in action.

Table 1. LOSS OF WEIGHT UPON IGNITION OF TYPICAL SOILS AT PEPEEKEO, HAWAII (March 1975)

Sample Number	Weight loss, %
23	26.25
24	27.59
25	27.38
26	26.91
27	27.08
28	27.17
29	26.03
30	28.29
32	27.29
33	26.34
34	27.10
Average	27.04

Inspection of Table 2 shows typical data illustrating differences between the old and new systems, in which the weekly average for CMH approaches the target value of 4 percent ash, which is estimated to be the amount of ash that represents an economically achievable level for the planned wastewater treatment facilities. Table 3 illustrates the type of information obtained by operating the old and new systems in the same field (Field F60-A). Note that the CMH on Day 3 (Tuesday) does achieve the required quality of performance with a reasonably good tonnage of gross material.

Table 4 is a comparison of four of the CMH techniques which provided the summary data for Table 3. There are at present only two of the new harvester-cleaners (pick-up cleaners) in operation. Machine 1 is equipped with blowers for leafy trash removal, but without special dirt-removal equipment. Machine 2 is a second-generation machine with dirt-removal facilities but without blowers. Machine 3, not completed at April 2, 1975, will have both the blowers and improved dirt-removal rolls. The "burned", "unburned", notations refer to whether or not the cane was burned before harvest to reduce the amount of leafy trash. Tables 2, 3 and 4 are illustrative of some of the combinations of data available from the recently developed technique for sampling and analysis of cane harvested by various methods. The technique is simple, reproducible and low cost, and allows testing to occur on routine production operations without interposing special conditions for testing. The accuracy of the method is satisfactory for measuring the relative performance of machinery harvesting a product difficult to sample in tonnage quantities. The absolute accuracy of the method, as it is described above, is probably not satisfactory.

Transportation and Cane Unloading System

The earlier developmental work on the transportation system envisioned an infield transporter, a mobile trans-loader at the roadside and a truck-trailer with a 30-ton capacity. The trans-loader was found to be an inefficient device which required too much time for positioning and unloading, dropped too much chopped cane at the roadside and tended to dig itself into the mud. This machine has been replaced by modified infield transporters which have a pivoted extendable box for loading directly into the trucks at roadside.

A completely new type of cane hauling unit for the Hilo Coast is to replace the conventional open-frame side-unloading semi-trailer trucks. The new units, when the program is fully implemented in 1977 will comprise 35 double trailer units with 12 cab-over-engine (COE) tractors. Ten of the trailer units (see Figure 5) have been delivered and will operate temporarily with conventional tractors until the COE units arrive.

Table 2. FACTORY SUMMARY, WEEK ENDING 2/22/75
(tons gross)

WAINAKU (LONG CANE)

Day	Material	% Ash	Tons ash	Unaccounted
1	1,538.64	11.87	182.65	329.28
2	2,825.74	11.69	330.34	20.98
3	2,716.15	11.44	310.66	
4	2,594.29	11.83	306.87	278.24
5	2,981.30	11.47	341.85	25.00
6	2,767.22	8.52	235.70	
7	483.61	10.09	48.80	27.55
WK	15,906.95	11.04	1,756.87	680.05
TD	100,883.33	9.45	9,532.48	3,385.21

PEPEEKEO (LONG CANE)

Day	Material	% Ash	Tons ash	Unaccounted
1	2,263.48	8.67	196.15	
2	2,589.44	7.91	204.72	
3	2,010.00	8.77	176.26	25.65
4	2,859.58	10.45	298.93	
5	2,316.55	9.51	220.29	
6	1,966.06	8.40	165.19	
7	445.22	8.55	38.05	
WK	14,450.33	8.99	1,299.59	25.65
TD	122,274.44	8.76	10,707.17	684.33

PEPEEKEO (CMH CANE)

Day	Material	% Ash	Tons ash	Unaccounted
1	0.00	0.00	0.00	
2	236.99	4.13	9.79	
3	361.62	4.52	16.35	
4	282.60	5.76	16.29	
5	285.12	5.37	15.31	
6	251.20	4.78	12.00	
7	298.17	4.48	13.35	
WK	1,715.70	4.84	83.09	0.00
TD	9,610.87	6.24	599.70	347.65

Table 3. PEPEEKEO FACTORY, WEEK ENDING 3/8/75
(tons gross)

FIELD F 27A

Day	Material	% Ash	Tons ash
1	0.00	0.00	0.00
2	457.78	5.30	24.26
3	1,484.47	8.43	125.11
4	1,596.05	8.79	140.34
5	1,054.72	8.10	85.40
6	1,109.12	8.15	90.37
7	437.31	8.59	37.58
WK	6,139.45	8.19	503.06
TD	6,139.45	8.19	503.06

FIELD F 60A-CMH

Day	Material	% Ash	Tons ash
1	0.00	0.00	0.00
2	131.78	5.45	7.18
3	225.82	3.52	7.96
4	264.07	5.52	14.58
5	235.41	6.04	14.23
6	223.99	5.29	11.84
7	0.00	0.00	0.00
WK	1,081.07	5.16	55.79
TD	10,811.25	6.12	661.25

FIELD F 27B

Day	Material	% Ash	Tons ash
1	1,056.14	5.45	57.56
2	903.26	6.65	60.05
3	0.00	0.00	0.00
4	0.00	0.00	0.00
5	0.00	0.00	0.00
6	0.00	0.00	0.00
7	0.00	0.00	0.00
WK	1,959.40	6.00	117.61
TD	5,770.59	7.22	416.62

FIELD V 55A

Day	Material	% Ash	Tons ash
1	0.00	0.00	0.00
2	71.49	4.84	3.46
3	0.00	0.00	0.00
4	0.00	0.00	0.00
5	0.00	0.00	0.00
6	338.69	9.88	33.45
7[a]	0.00	0.00	0.00
WK	410.18	9.00	36.91
TD	410.18	9.00	36.91

[a] 21.70 tons gross unaccounted.

FIELD F 60A

Day	Material	% Ash	Tons ash
1	0.00	0.00	0.00
2	991.67	6.43	63.76
3	2,190.15	8.61	188.60
4[a]	1,518.40	6.62	100.52
5	1,558.04	9.10	141.79
6	1,804.12	9.47	170.85
7	220.96	9.31	20.57
WK	8,283.34	8.28	686.09
TD	8,801.95	8.43	741.92

[a] 180.07 tons gross unaccounted.

FIELD P450

Day	Material	% Ash	Tons ash
1	394.17	5.58	21.99
2[a]	0.00	0.00	0.00
3	0.00	0.00	0.00
4	0.00	0.00	0.00
5	0.00	0.00	0.00
6	0.00	0.00	0.00
7	0.00	0.00	0.00
WK	394.17	5.58	21.99
TD	2,750.69	7.56	209.07

[a] 20.18 tons gross unaccounted.

Table 4. COMPARISON OF CMH EQUIPMENT - WEEK ENDING 3/8/75

Day	Description		Machine 1				Machine 2			M1 - M2 variance
		Code 4	Code 5	Code 6	Code 7	Sum/avg.	Code 8	Code 9	Sum/avg.	
1	Tons gross									
	% ash									
	Tons ash									
2	Tons gross			63.74		63.74		68.04	68.04	
	% ash			5.55		5.55		5.35	5.35	
	Tons ash			3.54		3.54		3.64	3.64	0.20
3	Tons gross							225.82	225.82	
	% ash							3.52	3.52	
	Tons ash							7.69	7.69	
4	Tons gross							264.07	264.07	
	% ash							5.52	5.52	
	Tons ash							14.58	14.58	
5	Tons gross						235.41		235.41	
	% ash						6.04		6.04	
	Tons ash						14.23		14.23	
6	Tons gross							110.24	110.24	
	% ash							5.52	5.52	
	Tons ash							6.08	6.08	-0.46
7	Tons gross				113.75	113.75				
	% ash				5.06	5.06				
	Tons ash				5.76	5.76				
WK	Tons gross			63.74	113.75	177.49	235.41	668.17	903.58	
	% ash			5.55	5.06	5.24	6.04	4.83	5.15	
	Tons ash			3.54	5.76	9.30	14.23	32.26	46.49	0.09
TD	Tons gross	274.10		63.74	165.54	503.38	2094.19	8213.68	10307.87	
	% ash	2.66		5.55	5.19	3.86	5.17	6.50	6.23	
	Tons ash	7.30		3.54	8.59	19.43	108.23	533.59	641.82	-2.37

Legend: Code 4 = blown/burned
Code 6 = blown/unburned
Code 5 = unblown/burned
Code 7 = unblown/unburned
Code 8 = burned
Code 9 = unburned

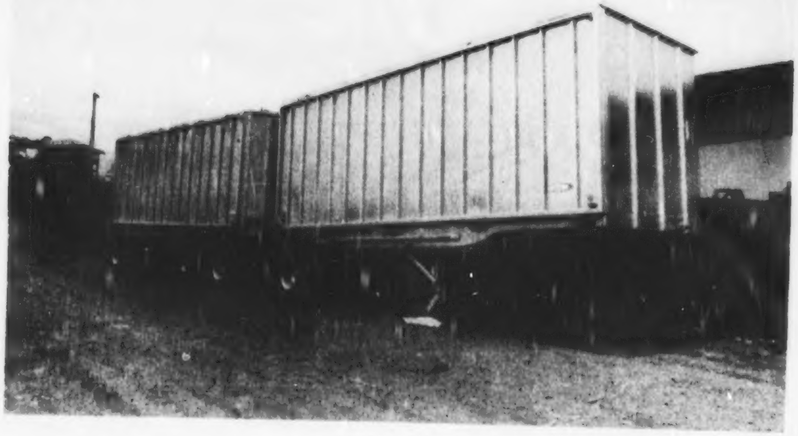


Figure 5. Double trailer unit for hauling cane.

A hydraulically-operated side dumping device 75 feet long has been installed at Papaikou. This dumper will tip the complete cane hauling truck-trailer assumbly to an angle of 30 to 55 degrees (adjustable). The sides of the trailers unlatch before tilting and permit the CMH cane to be discharged to the storage deck at the mill (Figures 6 and 7). Note the heavy-duty hold-down clamps for the trailers. The trailers will carry only cane harvested by the new machines.

Progress of the Abatement System

Harvesting---The first new harvesting pick-up cleaner machine began production operation about May 1, 1974. It began operations under very favorable conditions in that 1974 was a very dry year, especially from June to November, with only 120 inches of rain in the Hilo area. Soil loadings were nearly acceptable, though erratic. However, substantial rain returned in November just as the second machine began operations, and the quality of the CMH cane suffered severely.

The problem of soil entrainment, with its severe effect on the size of wastewater treatment facilities required, prompted re-evaluation of harvesting methods and revisions of old and new machines. A conventional V-cutter was modified with two rotating ground knives added on each side to replace the usual stationary ground knife (see Figure 8). The machine failed, first, because the stability of the cutter moving across the uneven terrain was insufficient to avoid digging into the soil, especially on moderate slopes and, second, because the operator could not get enough traction to move through the cane in wet weather. A typical stand of Hawaiian cane is shown in Figure 9. Note that the tangled mat of lodged (fallen) cane in the photo is about three feet deep. Some of the fallen cane clings to the ground like a creeping grass (which it is) and requires a substantial amount of power to dislodge it.

Modifications were made to the second pick-up cleaner by adding dirt-removal points, especially a set of pronged rolls developed by the US Department of Agriculture in Florida. These rolls, together with bar screens and conveyor changes have improved performance somwhat but not enough to meet the required objective of a maximum 4 percent ashed soil per ton of net cane. (Net cane is cane with no leaves, tops, roots, soil, rocks or other extraneous matter.)

Figure 10 shows the second pick-up cleaner harvester. The pick-up assembly has been split into two conveyors to provide a drop-out point for dirt at the transfer point between the two conveyors. The drums above the conveyors are to improve pick-up by compression of the cane mat. Figure 11 is taken immediately above the track of Machine 2 and shows dirt dropping out below the bar screen and Florida rolls.

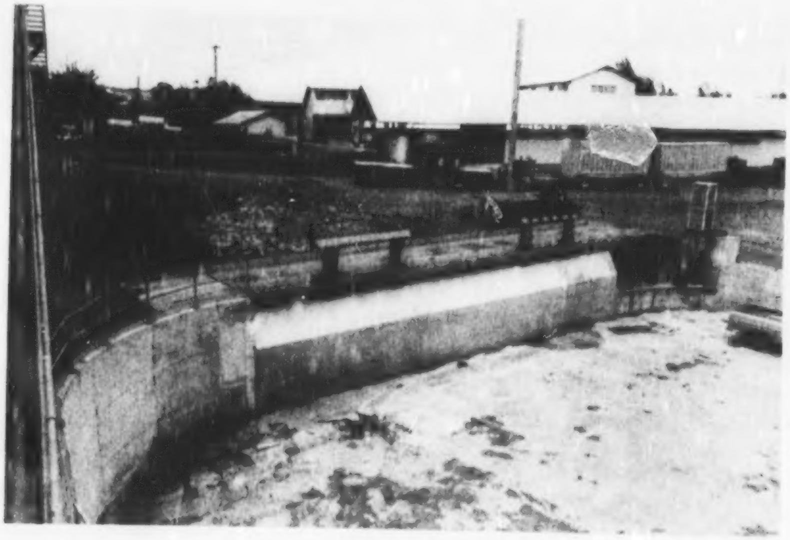


Figure 6. Cane storage deck at mill.

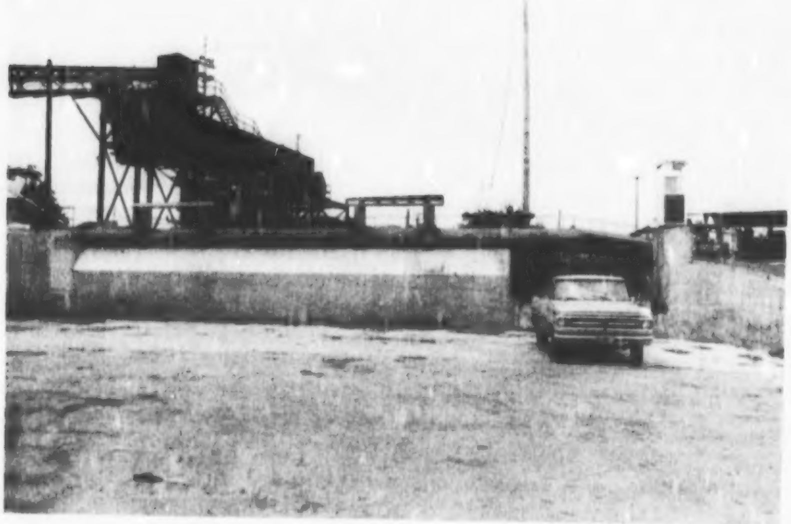


Figure 7. Storage deck.

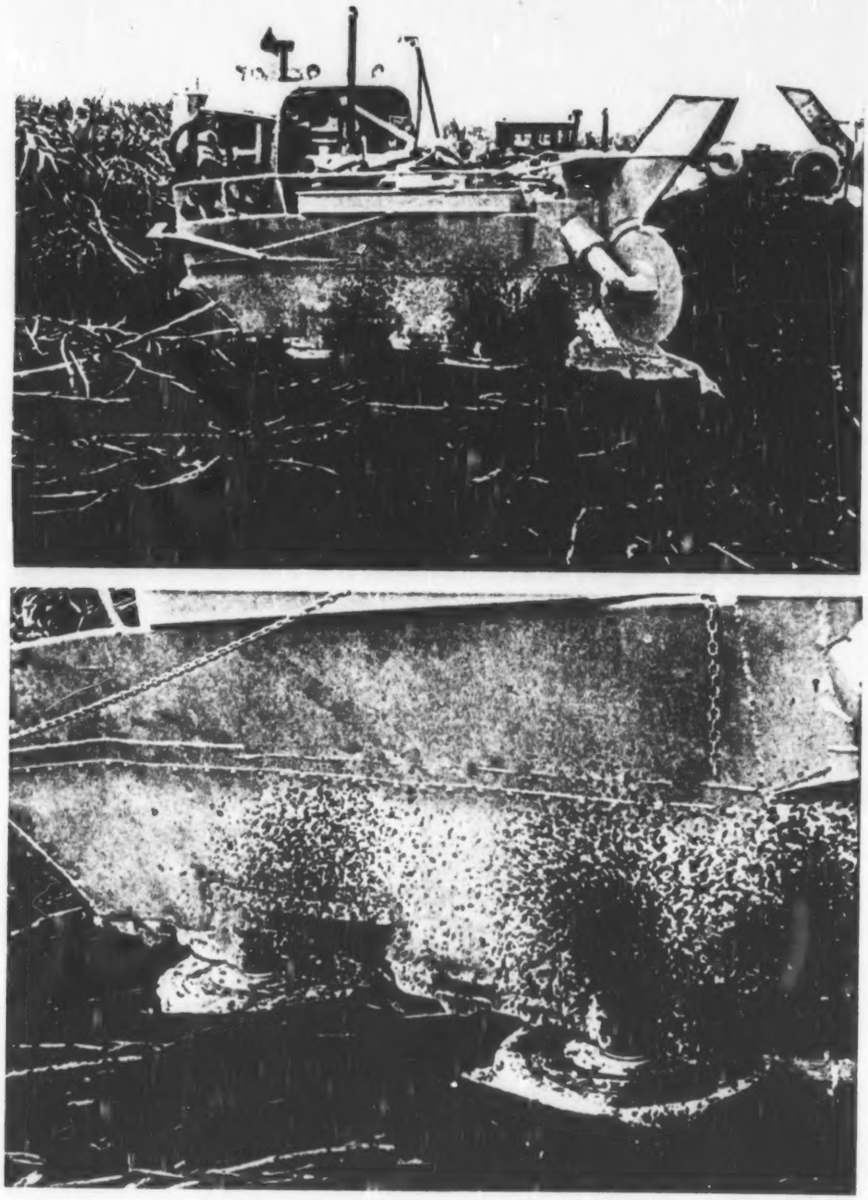


Figure 8. Vee cutter - rotary.
Hilo Coast Processing Company, May 1974.
(Continued next page.)

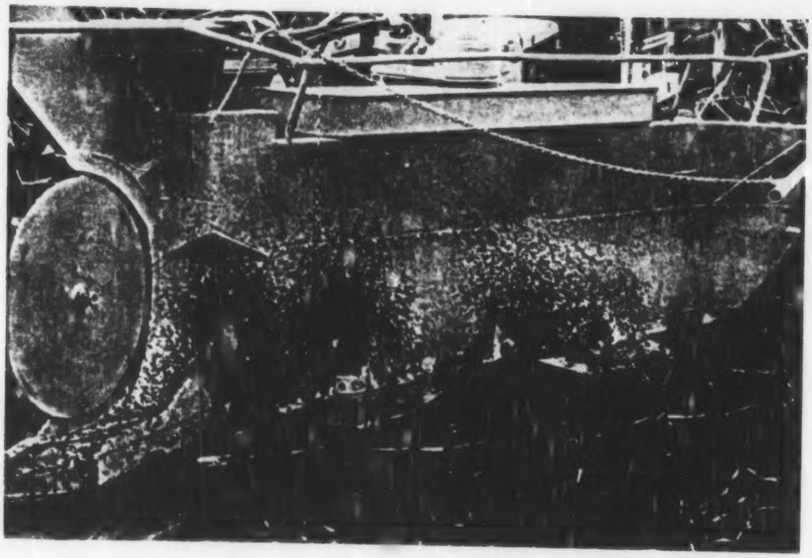


Figure 8 (continued). Vee cutter - rotary.
Hilo Coast Processing Company, May 1974.

Figure 9. Hawaiian sugar cane.

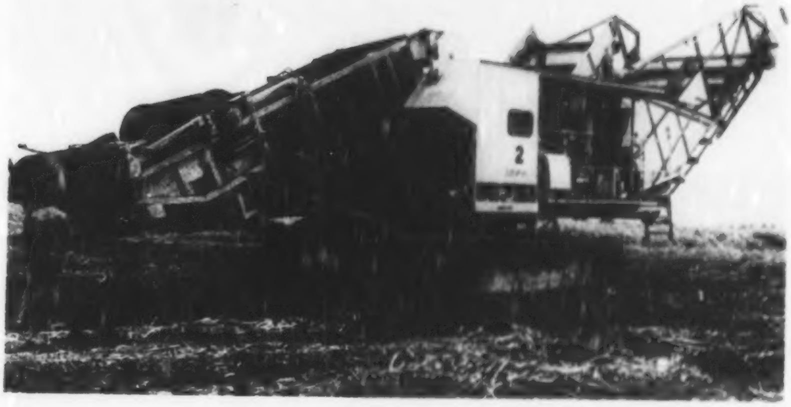


Figure 10. Cane pick-up cleaner harvester.

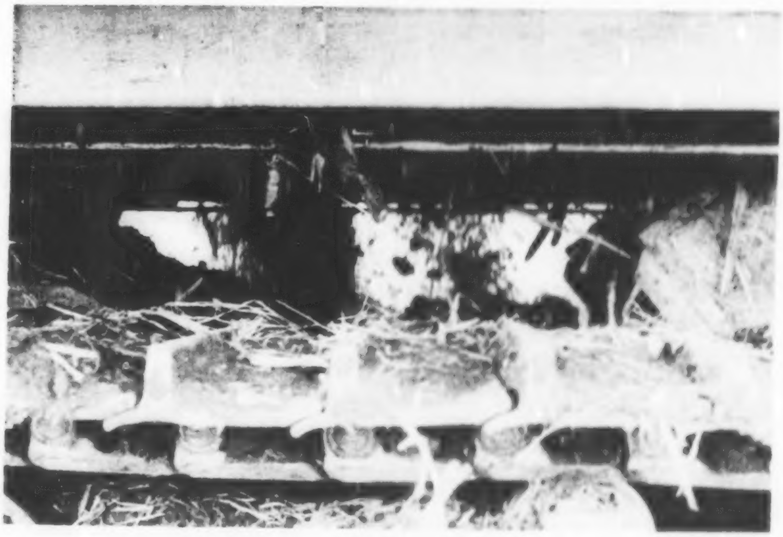


Figure 11. Close-up of harvester.

Machine 3 will represent a shift in harvesting philosophy on the Hilo Coast in that it will contain two cutter heads (ground knives), mounted just ahead of the pick-up chains. Tests made on a modification of an old experimental machine have indicated that it may be possible and advantageous to eliminate the V-cutting stage of harvesting. The negative factors are increased weight and complexity of the machine and reduced rate of production. The advantage is the possibility that an acceptable level of soil in cane may be achieved, a factor which completely outweighs disadvantages which were earlier thought to be insurmountable. The renewed emphasis on quality of raw material in order to minimize end-of-pipeline treatment at the factory has caused a significant change in operational objectives.

Cane Dry Cleaning---The cane dry cleaners at Papaikou and Pepeekeo became operational in 1974 and it quickly became evident that undue optimism had prevailed during the design of these units. In dry weather, with CMH cane, the cleaners worked moderately well. In wet weather, or with long cane, they failed miserably, hence, these two cleaners are being modified to permit dry cleaning for the leafy trash followed by wet cleaning for the remaining soil.

However, the dry removal of trash proved to be unexpectedly efficient in two ways. First, the method of dry removal appears to be much more efficient with respect to the quantity of trash removed than the conventional wet cleaning system. It is evident that no water should be used prior to the removal of trash by air blast. Second, large quantities of soil (up to 50 percent in early tests) are removed by and with the leafy trash. Some of the soil is occluded by the leaves and some is held by the rough surfaces of the leaves. This feature has provided an unexpected means of lowering cane wash-water suspended solids by a substantial, but variable, amount. The next phase will be to conduct an economic analysis to determine whether or not the cane trash should be washed, dewatered and burned for electric power generation or hauled away to waste land areas for disposal and eventual reclamation of the land for agriculture. It has become apparent that, with additional study and experience, it should be possible to select a combination of modes of operation of the harvesting equipment and of the cane cleaners to provide the optimum economic balance of the use of the components of the total pollution abatement system.

Electric Power Generation---This segment of the abatement system has been in operation on a commercial basis for nearly a year and is furnishing about 20 percent of the electrical power for the Island of Hawaii. At the time of writing the generation of power at full load using fibrous waste alone occurs on a partial basis pending final implementation of the shut-down schedule for the old factories, at which time more fibrous fuel will become available for the new power plant at Pepeekeo.

Indeed, the capability of the new installation is such that combustible municipal solid waste could be burned with ease once the non-combustible wastes were separated. The type of boiler installed at Pepeekeo, because of its requirement for larger than normal furnace volume to burn waste cane fiber, is well suited for burning other kinds of solid waste.

Figure 12 shows a portion of the fibrous fuel storage for the boiler and Figure 13 shows the 20,000 KW electric generator driven by high pressure steam from the boiler.

Effect of Certain Operational Parameters

The major independent variable affecting the total program is rainfall. This single element controls the amount of suspended soilds (soils) to be handled by all operations including the sugar processing and electric power generation. Several charts and graphs illustrate this factor rather vividly. Table 5 is the 75-year record of rainfall for a rain guage near the center of the cane farming area involved in the harvesting phase of the pollution abatement system. The lower section of the chart showing highs, lows and averages is of particular interest as a guide to the probably limits of the problem. This is followed by Figure 14, which shows, in tabular and graphic form, the distribution of rainfall in the area for the years 1969 to 1971, with a grouping of light, medium and moderate to heavy rainfall.

Fortunately, the period for November 25, 1974 to December 27, 1974 contained well-defined intervals of light, medium and moderate rainfall. This period coincided with the implementation on a production basis of the new procedures for determination of ashed soil in harvested cane. Compilation of the raw data in terms of the amount of ash (in tons) per ton of pol (sucrose) in the harvested cane provided a useful ratio for the determination of the effect of the amount of rainfall on the quality of the harvested material from the conventional harvesting method and the new CMH system.

The tons ash per tons pol ratio is useful because the amount of sugar in the cane, per acre, is reasonably constant for a particular field, hence provides a base for comparison of different techniques. The sugar content (pol) of the harvested cane is routinely determined by the core-sampling method described earlier and the data were available on a comparable basis, sample by sample. Inspection of Table 6, Dry Ash In Harvested Cane, shows that, for the period measured, the soil reduction efficiency of the new CMH system decreased with increasing rainfall and finally failed altogether. This situation resulted in the re-evaluation of harvesting operational philosophy which has been described. Note that Table 6 is based on "corrected rainfall".

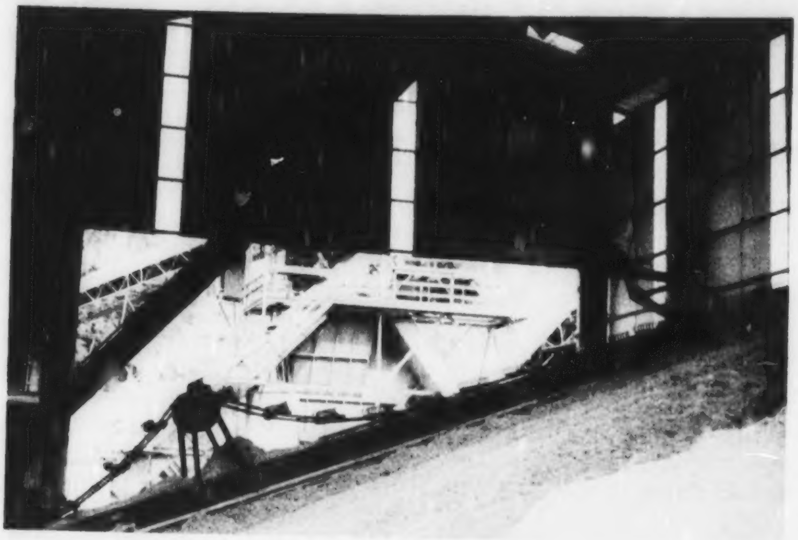


Figure 12. Storage of fibrous fuel.

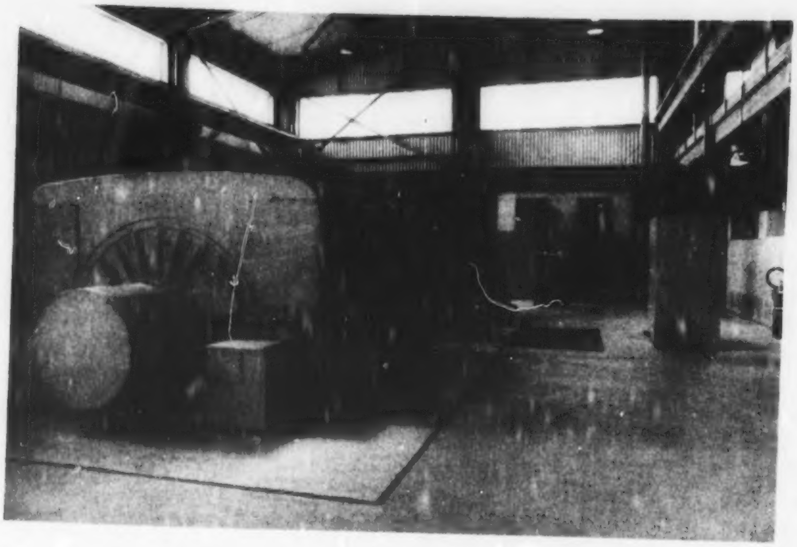
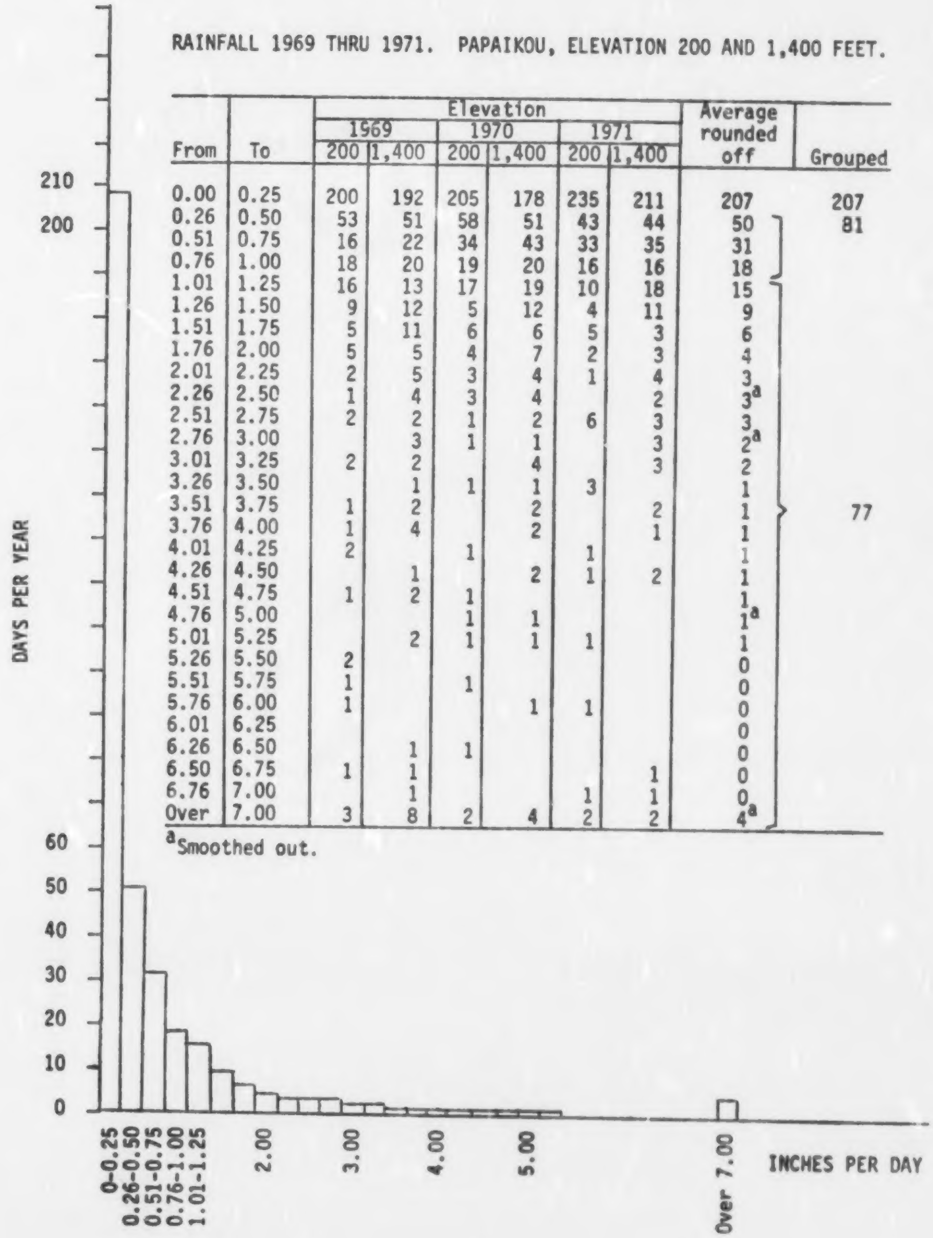


Figure 13. Electric generator.

Table 5. 1900 TO 1974 MONTHLY RAINFALL DATA - PAPAIKOU MAKAI STATION

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Monthly average
1900	1.99	5.81	5.66	6.37	16.85	3.42	11.27	13.57	8.13	23.65	18.36	2.01	116.79	9.73
1901	10.98	10.91	35.83	13.35	3.34	3.01	6.01	8.57	6.97	15.28	51.04	20.11	185.40	15.45
1902	4.75	4.51	81.29	13.97	27.16	6.67	17.18	25.11	16.29	19.23	23.42	26.04	265.62	22.14
1903	8.91	11.72	7.63	23.86	9.31	5.85	26.64	9.54	17.08	10.06	20.02	8.18	158.80	13.23
1904	32.52	12.88	1.62	38.04	8.78	9.60	20.36	17.10	10.16	5.20	8.91	4.71	169.88	14.16
1905	2.58	8.61	3.65	8.57	10.04	10.49	11.63	17.12	24.39	12.34	35.99	15.92	166.33	13.86
1906	6.36	2.69	3.21	11.13	10.77	7.24	14.44	25.60	9.59	6.67	18.45	19.47	135.62	11.30
1907	8.13	17.91	17.78	6.66	8.03	14.51	10.41	44.50	37.82	19.29	13.24	6.05	204.33	17.03
1908	11.86	26.33	7.54	23.29	13.17	9.77	11.75	15.81	20.83	16.65	9.28	18.23	184.51	15.38
1909	9.61	12.70	38.69	11.80	16.16	10.39	18.76	7.42	11.15	11.94	4.65	27.39	180.66	15.06
1910	26.87	4.62	21.44	14.15	17.56	14.74	14.47	18.85	7.47	9.79	15.51	18.03	183.40	15.29
1911	22.09	18.18	13.28	20.83	19.23	14.99	13.64	11.04	21.41	10.50	19.37	18.05	202.61	16.88
1912	0.97	18.58	16.54	25.78	9.34	11.89	8.07	9.99	8.20	23.91	17.13	21.05	171.45	14.29
1913	36.72	9.23	10.34	15.38	9.65	11.48	7.48	10.35	6.57	4.44	27.88	13.52	163.40	13.62
1914	10.97	4.43	11.24	11.04	32.53	29.24	32.28	48.67	39.02	11.50	20.63	15.60	267.15	22.26
1915	5.55	14.58	4.10	31.90	4.50	13.16	13.36	6.57	8.26	21.59	51.99	14.05	189.61	15.80
1916	14.05	2.58	15.81	16.22	30.95	15.57	12.26	24.00	16.29	13.62	25.10	45.48	231.93	19.33
1917	24.29	4.54	29.14	18.28	8.22	9.85	9.71	4.11	4.54	6.06	23.08	8.77	150.59	12.55
1918	27.13	41.10	39.88	36.00	29.31	12.59	34.73	18.03	9.70	11.92	24.14	28.73	313.26	26.11
1919	6.91	8.26	17.35	6.36	7.61	6.72	10.34	14.20	13.16	12.47	12.37	5.84	121.59	10.13
1920	5.77	6.19	36.65	8.36	2.11	5.04	10.98	8.76	15.01	19.99	11.49	14.93	145.28	12.11
1921	63.88	5.89	5.74	13.99	4.36	3.17	10.30	11.25	8.01	18.19	35.12	31.12	211.02	17.59
1922	32.96	29.50	69.73	18.69	11.32	3.64	7.64	11.97	21.21	11.73	27.17	3.90	249.46	20.79
1923	59.14	8.73	35.86	34.15	14.75	14.45	15.22	17.20	25.18	17.84	10.12	41.27	293.91	24.49
1924	3.47	9.08	8.54	34.91	6.87	4.31	18.11	17.72	10.69	26.37	10.65	4.56	155.26	12.94
1925	14.12	2.49	34.70	15.09	15.18	12.09	4.10	17.70	12.59	5.14	11.24	1.21	145.65	12.14
1926	3.56	6.56	1.71	2.15	7.76	4.10	5.20	17.57	9.97	7.12	5.00	15.85	86.55	7.21
1927	12.91	4.14	17.98	10.82	10.37	6.11	14.52	15.07	12.49	8.27	14.93	49.06	176.67	14.72
1928	8.46	5.48	5.27	7.23	10.16	7.27	16.22	9.38	11.30	13.43	7.24	26.88	128.32	10.69
1929	9.10	15.75	20.29	13.27	3.84	2.92	14.25	8.62	4.24	4.70	11.95	14.48	123.41	10.28
1930	5.64	4.38	12.69	30.82	11.51	20.69	9.41	21.30	15.04	10.33	19.43	6.79	168.03	14.00
1931	2.66	9.08	2.28	10.09	6.14	3.91	15.99	13.40	19.97	9.86	14.04	5.77	113.19	9.43
1932	29.02	30.95	4.70	12.02	13.06	7.55	12.43	6.89	6.05	2.74	10.70	14.87	150.98	12.58
1933	24.79	14.18	7.20	10.90	10.02	5.82	4.30	5.00	8.12	2.94	2.86	2.39	98.52	8.21
1934	14.45	4.77	3.12	10.03	14.08	9.30	8.47	5.71	13.67	16.91	8.50	18.31	127.32	10.61
1935	8.25	26.15	8.45	10.75	3.75	7.85	8.52	6.92	9.03	7.87	16.56	2.83	118.83	9.91
1936	5.35	4.40	19.51	15.37	11.88	5.57	14.11	27.42	21.97	16.19	7.65	39.71	189.13	15.76
1937	28.36	8.34	28.05	13.09	13.79	15.51	19.32	14.99	7.41	11.14	14.93	13.19	188.12	15.68
1938	22.10	14.65	31.17	27.66	14.70	6.75	3.74	6.26	4.69	9.20	14.59	13.29	168.80	14.07
1939	22.88	22.37	39.89	20.54	4.62	11.08	13.48	6.21	6.48	9.55	11.57	2.68	171.35	14.38
1940	1.06	5.05	4.41	3.87	5.41	4.65	11.40	23.88	9.97	17.93	9.21	3.60	100.44	8.37
1941	6.41	1.62	9.63	4.85	17.84	14.05	7.52	17.51	16.45	25.91	8.48	12.37	142.64	11.89
1942	1.64	5.45	43.31	19.59	9.53	6.17	6.41	12.14	6.32	10.39	3.59	15.09	139.63	11.64
1943	8.99	8.84	8.08	8.91	5.14	15.27	11.57	9.95	7.99	3.25	3.17	12.41	103.57	8.63
1944	3.43	20.30	1.76	14.34	13.05	5.95	14.10	7.41	8.39	13.93	14.62	20.42	137.70	11.48
1945	2.87	6.43	25.54	13.51	1.19	9.01	4.86	14.26	5.60	6.88	13.92	18.69	122.76	10.23
1946	23.62	9.33	12.56	12.97	2.87	4.06	12.03	7.00	5.65	9.49	5.86	48.17	153.61	12.80
1947	3.30	3.26	18.11	8.75	10.62	6.04	9.66	14.79	10.60	13.97	16.13	25.09	140.32	11.69
1948	6.12	10.16	34.97	12.89	13.11	4.60	8.19	7.44	7.92	15.08	18.45	25.90	164.83	13.74
1949	33.17	8.45	12.10	7.65	4.43	3.48	8.88	7.80	6.97	10.71	11.74	16.44	131.82	10.99
1950	9.71	25.47	6.81	28.37	18.65	4.34	9.10	6.17	4.71	10.42	9.44	14.20	147.89	12.32
1951	9.06	27.05	17.76	5.81	3.82	4.31	12.26	11.24	3.18	24.24	14.58	16.84	150.15	12.51
1952	18.83	8.18	18.02	8.99	9.33	10.18	7.08	7.31	7.94	10.52	13.63	8.58	128.59	10.72
1953	0.15	11.75	21.56	4.63	11.97	4.98	5.21	5.84	4.16	6.95	7.03	8.97	93.20	7.77
1954	4.93	15.33	17.09	3.12	11.84	7.03	14.59	15.45	9.80	9.40	11.61	49.96	170.15	14.18
1955	12.84	23.99	10.24	18.32	10.71	5.90	10.74	9.31	6.72	6.22	15.09	7.77	137.85	11.49
1956	9.94	37.90	16.88	7.96	16.02	9.41	5.92	17.08	2.80	14.69	23.66	9.99	172.25	14.35
1957	11.46	7.71	3.95	21.89	8.88	4.66	12.62	31.22	3.16	20.40	11.47	20.37	157.79	13.15
1958	2.60	4.30	5.56	5.88	9.28	7.65	15.16	21.05	7.94	15.20	15.09	3.70	113.41	9.45
1959	10.07	11.82	10.46	9.93	8.58	4.25	6.70	8.71	8.84	4.67	29.78	14.17	127.98	10.67
1960	22.12	16.23	9.37	16.95	12.82	6.58	7.78	13.31	14.29	14.07	15.16	4.45	153.[illegible]	12.76
1961	3.17	24.00	5.90	7.34	9.66	5.83	8.34	8.75	7.99	28.68	15.55	17.99	143.20	11.93
1962	2.72	5.33	12.13	4.32	15.46	3.49	7.81	5.98	11.75	2.87	6.35	3.06	81.27	6.77
1963	1.66	2.21	16.93	34.54	15.47	11.10	15.15	8.57	13.07	13.75	11.77	1.64	145.86	12.16
1964	16.60	17.28	21.10	11.50	30.24	6.07	8.09	8.00	14.67	11.42	24.67	9.86	179.50	14.96
1965	9.80	5.56	6.81	18.51	17.54	9.04	10.99	4.46	6.30	8.57	21.26	17.84	136.68	11.39
1966	11.80	6.21	6.44	5.71	6.52	7.52	17.62	10.12	10.57	17.04	18.98	13.67	132.20	11.02
1967	9.39	8.90	9.33	20.30	12.22	7.79	18.85	22.52	6.17	6.55	29.67	20.96	172.65	14.39
1968	5.53	13.37	11.84	33.13	2.85	10.01	7.68	8.91	12.40	6.57	6.78	27.45	146.52	12.21
1969	13.31	52.24	36.76	17.94	7.11	2.65	12.70	25.28	11.56	3.02	7.28	11.77	201.62	16.80
1970	6.06	1.92	6.83	32.04	29.51	7.56	14.55	25.23	7.89	10.09	7.30	43.00	191.98	16.00
1971	13.87	7.86	15.24	27.15	6.96	3.38	7.53	3.41	8.65	8.87	26.37	35.05	164.34	13.70
1972	10.42	19.56	1.52	24.71	7.28	6.02	11.11	13.99	6.89	15.00	19.10	4.47	140.07	11.67
1973	3.69	6.11	21.48	8.56	9.18	5.10	6.24	3.25	10.95	9.91	32.03	13.27	129.77	10.81
1974	6.27	8.28	15.23	21.50	9.75	4.92	7.48	5.39	2.43	7.03	9.39	22.80	120.47	10.04
TOTAL	966.72	920.70	1,276.26	1,179.04	867.62	611.86	887.38	1,022.22	830.84	909.31	1,216.49	1,250.33	11,948.77	
AVG.	12.89	12.28	17.02	15.72	11.57	8.16	11.83	13.63	11.08	12.12	16.22	16.80	159.32	13.28
HIGH	63.88	52.24	81.29	38.04	32.55	29.24	34.73	48.67	39.02	28.68	51.99	49.96	313.26	26.11
LOW	0.15	1.62	1.52	2.15	1.19	2.92	3.74	3.25	2.43	2.74	2.86	1.64	81.27	6.77



RAINFALL 1969 THRU 1971. PAPAIKOU, ELEVATION 200 AND 1,400 FEET.

From	To	Elevation						Average rounded off	Grouped
		1969		1970		1971			
		200	1,400	200	1,400	200	1,400		
0.00	0.25	200	192	205	178	235	211	207	207
0.26	0.50	53	51	58	51	43	44	50	81
0.51	0.75	16	22	34	43	33	35	31	
0.76	1.00	18	20	19	20	16	16	18	
1.01	1.25	16	13	17	19	10	18	15	77
1.26	1.50	9	12	5	12	4	11	9	
1.51	1.75	5	11	6	6	5	3	6	
1.76	2.00	5	5	4	7	2	3	4	
2.01	2.25	2	5	3	4	1	4	3	
2.26	2.50	1	4	3	4		2	3[a]	
2.51	2.75	2	2	1	2	6	3	3	
2.76	3.00		3	1	1		3	2[a]	
3.01	3.25	2	2		4		3	2	
3.26	3.50		1	1	1	3		1	
3.51	3.75	1	2		2		2	1	
3.76	4.00	1	4		2		1	1	
4.01	4.25	2		1		1		1	
4.26	4.50		1		2	1	2	1	
4.51	4.75	1	2	1				1	
4.76	5.00			1	1			1[a]	
5.01	5.25		2	1	1	1		1	
5.26	5.50	2						0	
5.51	5.75	1		1				0	
5.76	6.00	1			1	1		0	
6.01	6.25							0	
6.26	6.50		1	1				0	
6.50	6.75	1	1				1	0	
6.76	7.00		1			1	1	0	
Over	7.00	3	8	2	4	2	2	4[a]	

[a] Smoothed out.

Figure 14. Rainfall frequency distribution.

Table 6. DRY ASH IN HARVESTED CANE[a]

Rainfall, inches/day (corrected[b])	Tons ash/Tons pol		Ash/pol reduction in percent
	Conventional harvest	Harvester - cleaner	
0.0-0.25	1.00	0.55	45.0
0.26-0.75	1.25	1.00	20.0
Over 0.75	1.36	1.41	-3.7

[a] Data based on period November 25-27, 1974.

[b] Corrected rainfall = ¼ day before yesterday + ¼ of yesterday + ½ of today.

This was found to be necessary because of the lag in harvesting operations from the time the field is first opened up and V-cut to the time the cane is loaded into the trucks. If this compensation for the operating lag is not made the scatter-gram of data is undecipherable.

If the data shown in Table 6 are used to estimate reduction in annual ash loadings the plot shown in Figure 15 results. Such extrapolation is useful only to indicate order-of-magnitude effects which in this case are shown to be total reduction of about 43,000 tons dry ash per year, corresponding to about 59,000 tons dry soil or about 200,000 tons of soil at 70 percent moisture (normal moisture for soil in the area). Aside from the costs of wastewater treatment itself, the cost of hauling this excess material back and forth from field to factory to field would approach $1,000,000.00 per year at 1974 trucking costs.

Analysis of Economic Effects

In December, 1974, the environmental engineering firm of Sunn, Low, Tom and Hara of Honolulu were asked to prepare an up-date of a prior report on wastewater management alternatives and to indicate estimated costs for several alternatives being considered by the Hilo Coast Processing Company. The alternatives were these:

1. Construct a wastewater treatment plant to handle 1,400 tons dry solids per day at ten million gallons per day hydraulic loading. This alternative was, in effect, end-of-pipeline treatment.
2. Construct a plant with 350 tons per day dry solids loading capability at 5 million gallons per day hydraulic loading.
3. Construct temporary pre-treatment facilities to handle the peak loads between 350 tons per day and 1,400 tons per day until the CMH and cane cleaner programs are fully effective.

The preliminary construction cost estimate for these alternatives are shown in Table 7 and some of the unit costs based on 1974 construction costs in Hawaii are shown in Table 8. These costs were for the Pepeekeo factory only and similar, but lower, costs were developed for the smaller plant at Papaikou.

The 350 tons dry solids per day level of plant size represents the plant needed for a harvesting quality of 4 percent ash on net cane, assuming that all cane trash from Papaikou is washed and burned at Pepeekeo. About 100 tons per day excess capacity is built in to handle peak loads.

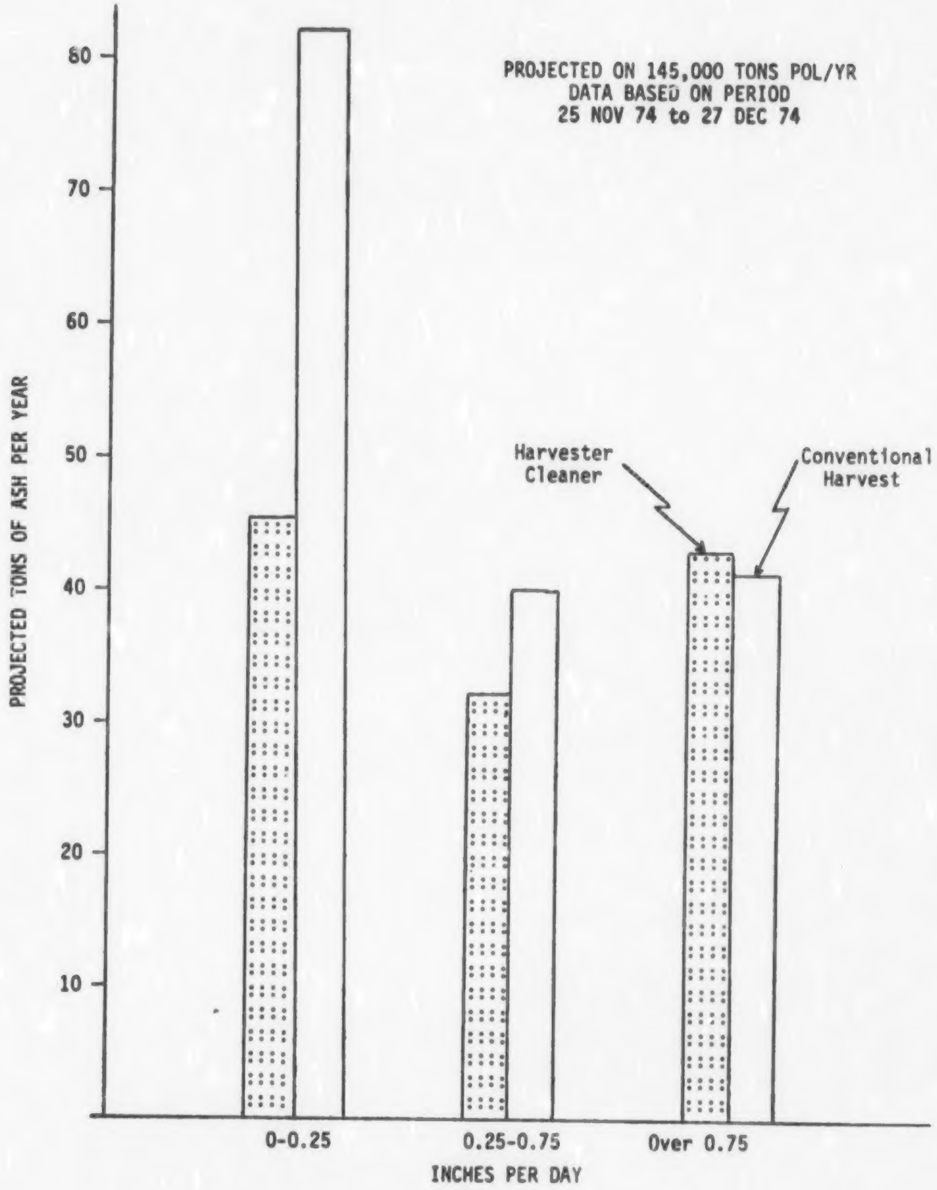


Figure 15. Ash versus daily rainfall (corrected).

Table 7. PRELIMINARY CONSTRUCTION COSTS[a]

Unit Process	Settling and thickening ponds	Cascading ponds	Gulch ponds	Ditches	Full-size treatment	350 TPD plant
Mill Interface						
1. Grit chamber	$ 140,000	$ 140,000	$ 140,000	$ 140,000	$ 140,000	$ 140,000
2. Pump station	707,000	1,061,000	1,061,000	1,061,000	707,000	707,000
3. Transmission lines	309,000	1,431,000	816,000	1,853,000	280,000	140,000
Subtotal	$ 1,156,000	$ 2,632,000	$ 2,017,000	$ 3,054,000	$ 1,127,000	$ 987,000
Pretreatment						
4. Sedimentation	$ 1,892,000	$ 5,850,000	$ 2,435,000	$ 4,217,000		
a. Pond construction	7,228,000	7,228,000	7,228,000	7,228,000		
b. Slurry dewatering	1,340,000	1,960,000	2,006,000	2,960,000		
c. Solids disposal equipment						
5. Pumping/recycling						
a. Pump stations		1,414,000	707,000	707,000		
b. Transmission lines	135,000	480,000	230,000	281,000	255,000	
c. Odor and quality control	( )[b]	( )	( )	( )	( )	( )
Subtotal	$10,595,000	$16,932,000	$11,630,000	$14,393,000	$ 255,000	( )
Treatment and Disposal						
6. Treatment						
a. Flocculators	$ 157,000	$ 157,000	$ 157,000	$ 157,000	$ 157,000	$ 157,000
b. Clarifier	1,040,000	1,040,000	1,040,000	1,040,000	4,407,000	1,040,000
c. Thickener	679,000	679,000	679,000	679,000	2,794,000	679,000
d. Dewatering	1,278,000	1,278,000	1,278,000	1,278,000	5,112,000	1,278,000
e. Solids disposal equipment	230,000	230,000	230,000	230,000	966,000	230,000
f. Pump and control building	501,000	501,000	501,000	501,000	1,542,000	501,000
g. Exterior piping and electrical	163,000	163,000	163,000	163,000	423,000	163,000
h. Site work	192,000	192,000	192,000	192,000	317,000	192,000
7. Effluent disposal line	140,000	140,000	140,000	140,000	25,000	140,000
Subtotal	$ 4,380,000	$ 4,380,000	$ 4,380,000	$ 4,380,000	$15,743,000	$ 4,380,000
Solids Disposal Site						
8. Site development	$( )	$( )	$( )	$( )	$( )	$( )
9. Roadways						
Subtotal	$( )	$( )	$( )	$( )	$( )	$( )
GRAND TOTAL	$16,131,000	$23,944,000	$19,003,000	$21,827,000	$17,125,000	$ 5,367,000

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[a] Costs are based on 1974 prices.

[b] ( ) indicates additional major cost items are not defined.

Table 8. UNIT COSTS USED IN PRELIMINARY ESTIMATES (September 1974)

1. Concrete		
Makakilo STP	$450-$760/cy	
Hawaii Kai STP IV-A	$370-$460/cy	Use $500.00/cy
2. Structural Excavation		
Makakilo STP	$30-$70/cy	
Hawaii Kai STP	$130$25/cy---soil w/mud rock	Use $20.00/cy
3. Mass Excavation		
Pearl Harbor Interchange (large quantity)	$2.24-$5.10/cy---rock	
HECO (Waiau - small pond)	$4.00/cy---soil and coral	Use $3.00/cy
4. Embankment		
Pearl Harbor Interchange (large quantity)	$2.50-$3.50/cy---rock	
HECO (Waiau - small pond)	$4.00/cy---soil and coral	Use $3.00/cy
5. Piping - In Place Complete (assume in soil with 5 feet cover)		
Makaha Meadows - 6 inch line	$23.00/lf	
Ehukai Sewer - 24 and 30 inch lines	$80.00/lf	

Use the following:

Pipe size (inches)	8	10	12	16	20	24	30
Cost/lf (dollars)	27	30	35	45	55	70	90

6. Dam (end dump of boulders)		
Reef Runway - $16.00/ton x 1.4 tn/cy =	$22.40/cy	Use $23.00/cy
7. Filter Material (in place complete)		
Nawiliwili Boat Harbor	$0.65-$0.90	Use $1.00/sf
8. Roadway		
Excavation - Makakilo Mala Access Road	$3.80-$12.50/cy	Use $7.00/cy
Crushed Rock - Makakilo Mala Access Road	$2.85-$3.00/sy	Use $3.00/sy
Wooden Curbing - Makakilo Mala Access Road	$3.70-$4.00/lf (concrete)	Use $3.00/lf
9. Sludge Collecter (rectangular)		
Makakilo STP - 18' wide x 40' lg tank	$42,000	Interpolate in different sizes
Hawaii Kai STP - 16' wide x 100' lg tank	$60,000	
Hawaii Kai STP - 20' wide x 86' lg tank	$60,000	
10. Sludge Collector (circulat)		
Schofield STP - 55' primary	$36,000	
Schofield STP - 60' secondary	$44,000	

11. Plug Valves

Pipe size (inches)	6	8	10	20	24
Material cost	210	310	610	2,600	5,200
Installation cost	190	190	390	1,400	1,800
Cost/lf (dollars)	400	500	1,000	4,000	7,000

The quality requirements for the suspended solids removal by the wastewater treatment plant were in the range of 93 percent to 96 percent, depending upon load, and were based on NPDES permit requirements. It was obvious, once again, that end-of-pipeline treatment was financially impossible and that the CMH quality standard of 4 percent ash entrainment had to be met.

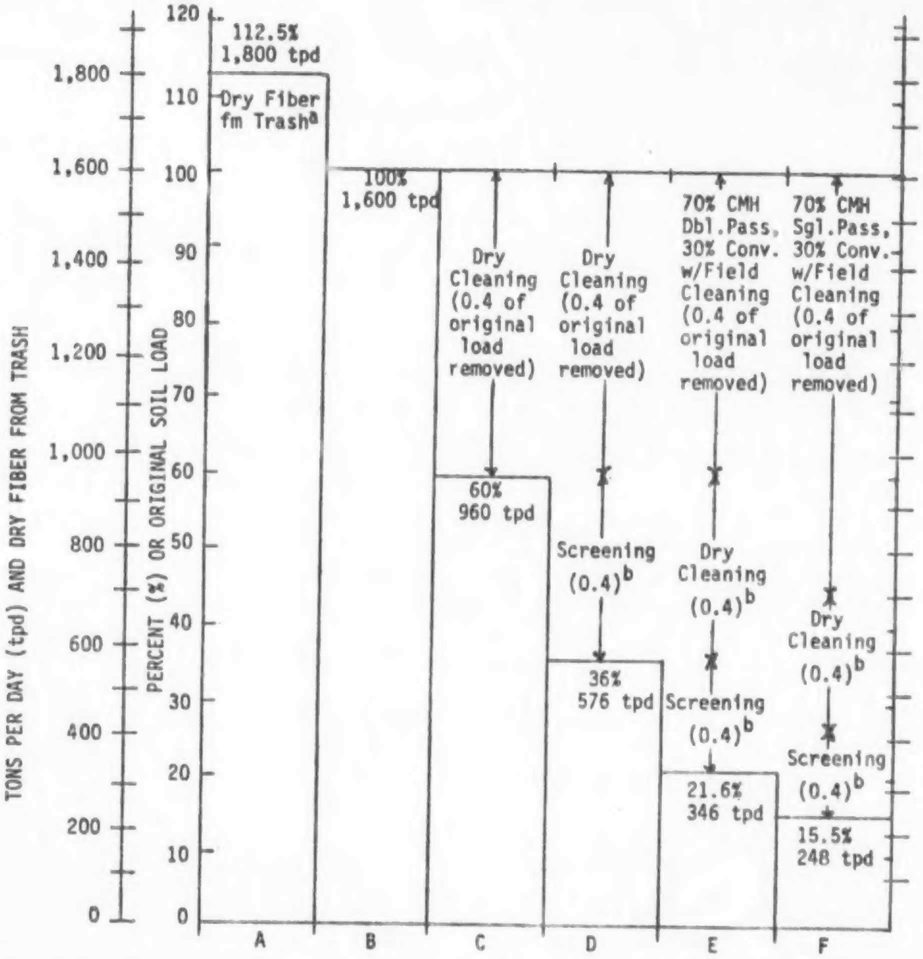
The Cane Materials Handling System, the success of which is fundamental to the success of the total water pollution abatement program also has certain capital investment, leasing and operating costs involved. The CMH portion of the program has required a commitment of $6,483,000 for the period 1974 to 1977.

The projected capital and operating costs of the wastewater treatment facility at the Pepeekeo factory through 1978 are as follows:

	1975	1976	1977	1978
Capital Cost				
350 tons per day (1974 dollars, unescalated)	$450,000	$4,971,000	$ -	$ -
Operating Costs				
(Escalation)	10%	14%	10%	10%
Services	-	-	623,800	686,200
Payroll	-	-	491,900	541,100
Material	-	-	392,000	431,600
Fixed Charges	-	110,900	801,800	801,800
TOTAL	-	$110,900	$2,309,900	$2,460,700

The cost estimates are based on the 350 tons dry solids per day plant capacity which is judged to be adequate under all conditions if the elements of the abatement system operate as shown in Table 9, Column E. Table 9, based on the most recent and most pessimistic data available, indicates that the system will achieve the required levels of abatement if all elements of the system operate as predicted. The maximum level of entrained soil shown in Column B, Table 9, at the 100 percent level, is that amount which occurs in very wet weather using conventional harvesting methods. These methods are being phased out as CMH equipment becomes available and thus the predicted maximum load to be handled at the factory shifts downward in Columns E and F, Table 9, to the bottom of the first vertical arrows in these columns.

Table 9. WET CONDITIONS, EXPECTED SOIL LOAD TO WATER TREATMENT FACILITIES



	A	B	C	D	E	F
Tons Dry Soil from Field	1,600	1,600	1,600	1,600	960	688
Net Tons Cane	5,050	5,050	5,050	5,050	5,050	5,050
Ratio	.317	.317	.317	.317	.190	.136

[a] Estimate of Tons Dry Fiber from Trash: 5,050 Net Tons Cane/Day ÷ 110 Tons Cane/Acre = 45.9 Acres/Day. 45.9 Acres/Day x 5.6 Tons Dry Fiber/Acre x 778 = 200 Tons Dry Fiber/Day.

[b] Of remaining Soil Load removed.

The required efficiency of the water treatment system under the different loading conditions shown in Table 9 is illustrated in Table 10 for the limits set under existing NPDES permits. The limits are set, as can be seen, in such a way that the annual efficiency required for suspended solids (soil) removal is 92 percent to 94 percent with a fully implemented CMH program and up to 98 percent with conventional harvesting but with trash hauled away (not washed) and with cane cleaner wash water screened through fine mesh static screens. This chart (Table 10) once again emphasizes that end-of-pipeline treatment is impractical in that it is very doubtful that 98 percent efficiency could be achieved as an annual average on a continuous 46-week annual operation.

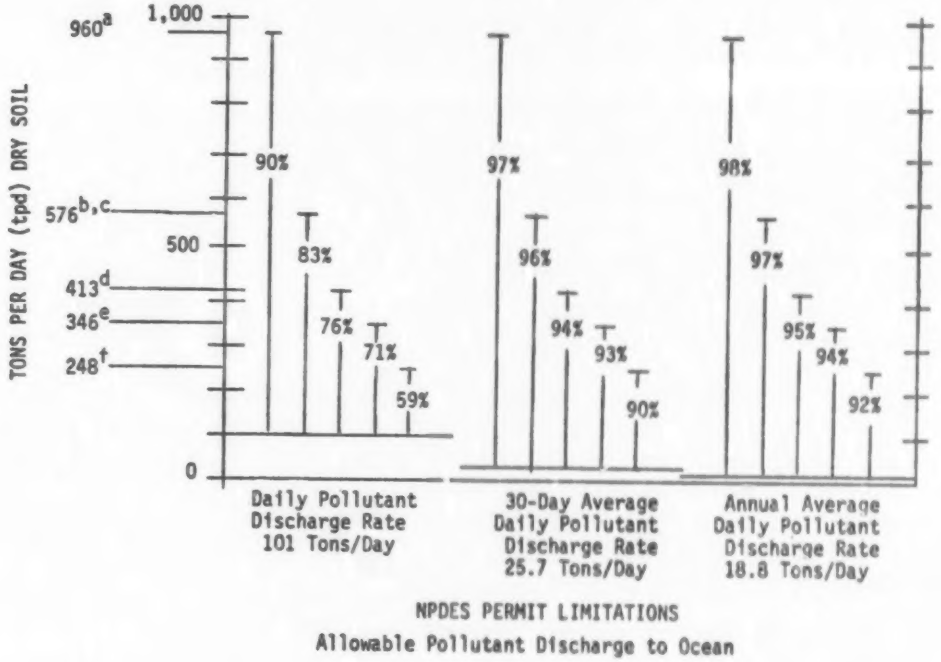
CONCLUSIONS

An over-view of experience to date with the elements of the wastewater pollution abatement program would indicate that the most probable alternatives to be followed in the future are these:

1. Field areas now inaccessible to the CMH machines (approximately 30 percent of the total area in cane) will be moved to roadsides by conventional methods and will then be picked up by the pick-up cleaner harvester and delivered directly into trucks, thus performing a field-cleaning operation on the cane before hauling in order to reduce soil pick-up.
2. Leafy cane trash will be handled two ways in wet weather.
   a. Pick-up cleaner harvester blowers will be used.
   b. Dry cane cleaner trash will be hauled away for land reclamation.
3. Third generation pick-up cleaner harvesters will be single-pass machines with dual cutting heads and a laterally adjustable cutting and pick-up assembly which will permit offset cutting to avoid crushing uncut cane.
4. Wastewater management will include every feasible method for reducing both solids loading and hydraulic loading to the treatment plant.

It is also probable that more new CMH equipment will come into use in the harvest field than is now foreseen as the shift in emphasis toward better quality of harvested cane becomes increasingly evident.

Table 10. WET CONDITIONS, PERCENT SOIL REMOVAL BY WATER TREATMENT FACILITY REQUIRED TO MEET NPDES PERMIT LIMITS



[a] 960 tpd. Conv. Harv., all trash recovered, soil load reduced by 0.4 with screening.

[b] 576 tpd. Conv. Harv., no trash recovered, soil load reduced by 0.4 with dry cleaning, and remaining load reduced by 0.4 with screening.

[c] 576 tpd. 70% CMH double pass harv., 30% Conv. Harv., with field cleaning, all trash recovered, soil load reduced by 0.4 with screening.

[d] 413 tpd. 70% CMH single pass harv., 30% Conv. Harv., with field cleaning, all trash recovered, aoil load reduced by 0.4 with screening.

[e] 346 tpd. 70% CMH double pass harv., 30% Conv. Harv. with field cleaning, no trash recovered, soil load reduced by 0.4 with dry cleaning and remaining load reduced by 0.4 with screening.

[f] 248 tpd. 70% CMH single pass harv., 30% Conv. Harv. with field cleaning, no trash recovered, soil load reduced by 0.4 with dry cleaning, and remaining load reduced by 0.4 with screening.

UTILIZATION OF CHEESE WHEY FOR WINE PRODUCTION*

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Peter K. Larson**

INTRODUCTION

Effective and economical methods of utilizing whey are essential if cheese plants are to remain competitive with other segments of the food processing industry. The drying of cheese whey is limited by some adverse economic considerations. An efficient whey drying operation requires more whey than most cheese plants produce. Also, large volumes of water would have to be removed, thus requiring considerable consumptions of our diminishing energy resources.[1]

Utilization of whey for wine production requires little or no energy resources. The entire whey is utilized; no removal of water is necessary. Furthermore, whey can be utilized by small cheese plants for wine production, since no elaborate or expensive equipment is required.

Acceptable wine also has a higher monetary value than other products. From 100 pounds of milk, 10 pounds of cheese is produced; the remaining 90 pounds is whey. Ten pounds of cheese can be retailed for approximately $15; 90 pounds of whey can be made into 10 gallons of whey wine and be retailed for about $50, assuming $1 per fifth bottle. The economic advantage of utilizing whey for wine production is obvious.

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The use of whey as a fermentation substrate has appealed to microbiologists, food scientists, cheese processors, and others who have been faced with the problem of upgrading this raw material into useful products which can be produced and marketed on a profitable basis. Whey has been used or suggested as a substrate for the manufacture of yeast, alcohols, lactic acid, vitamins, vinegar, and alcoholic beverages. The production of wine or other popular alcoholic beverages from whey has remained a laboratory curiosity for many years.[5]

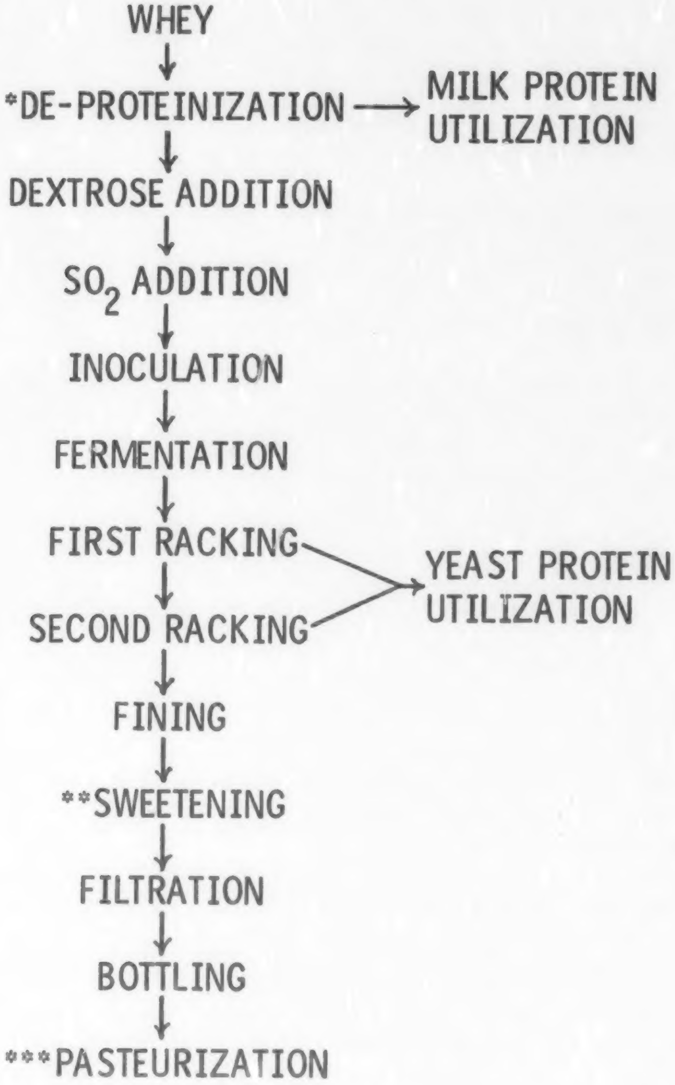
As early as 1868, a US patent was granted to Baldwin[3] for the production of a cordial from whey. In 1948 and 1952, Engel[4,5] was issued several patents for the production of an alcoholic beverage, in which sucrose and whey were fermented with baker's yeast. A variety of beer-like products have also been produced from whey in Germany.[6]

The US cheese industry is in most urgent need of a development of a whey by-product that would not encompass relatively expensive processes for water removal. The fermentation of sugar fortified whey by selected wine yeast and the production of an acceptable whey wine may represent a "near ideal" solution for the whey disposal and utilization dilemma of the US cheese industry. The production of an acceptable wine by whey fermentation may be the means of transposing a "cost of doing business" into a "profit opportunity". These, then, are the objectives of this project that would hopefully be carried to reality.

METHODS

Whey for this project was obtained from cheese plants located in Oregon and Washington. Thus far, cheddar cheese whey has been used for the experiments.

The general scheme of wine production from whey is shown in Figure 1. For making clear whey wine, it is necessary to de-proteinize the whey. This is done by heating the whey to 180 degrees F for five minutes. The protein thus precipitated is removed and could be utilized as food ingredients. About 22 percent of dextrose is added to the clear whey, depending on the concentration of alcohol desired in the wine. After cooling, 100 parts per million of sulfur dioxide is added for stability. The whey is then inoculated with yeast. Fermentation commences shortly thereafter. When fermentation is completed and yeast cells are settled, the wine is racked. This procedure is repeated once or twice. The lees are a good source of protein and could be used in foods or animal feeds. The wine is then aged and clarified by a fining agent. It is sweetened, if a sweet wine is desired. To insure clarity,


WHEY
*DE-PROTEINIZATION
MILK PROTEIN UTILIZATION
DEXTROSE ADDITION
SO2 ADDITION
INOCULATION
FERMENTATION
FIRST RACKING
YEAST PROTEIN UTILIZATION
SECOND RACKING
FINING
**SWEETENING
FILTRATION
BOTTLING
***PASTEURIZATION

*Omitted if a cloudy wine is produced
**Omitted when a dry wine is produced
***Omitted if an aseptic method is used

Figure 1. Production of sweetened clear whey wine.

the wine is filtered before bottling. Sweet wine should be pasteurized, or handled aseptically, to prevent secondary fermentation.

RESULTS AND DISCUSSION

Yeast

Table 1 shows the effect of different wine yeast strains on the fermentation rate of whey wine. Of the five yeasts tested, Montrachet fermented the fastest, taking an average of seven days to ferment whey to wine at room temperature. Champagne and Sherry were only slightly slower, taking eight days. Port took 12 days, and Burgundy 14 days. All yeasts produced the same alcohol content at the end of the fermentation, above 10 percent by volume. Sensory evaluation conducted thus far reveal no conclusive difference in flavor between wines fermented by different yeast strains. It appears that Montrachet is the preferred yeast for whey wine fermentation due to the more rapid rate of fermentation.

Temperature

Three fermentation temperatures were tested for their effect on the rate of fermentation and flavor of wine. Results are shown in Table 2. At the incubator temperature of 90 degrees F, it took an average of only four days for Montrachet yeast to ferment whey to wine; at room temperature, it took seven days. In a refrigerated room at 55 degrees F, fermentation was the slowest; 17 days were required for completion. The slightly lower alcohol content of the wine fermented at 90 degrees F could be due to the volatile nature of alcohol at higher temperatures.

Sensory evaluation revealed no significant difference between the wine fermented at 55 degrees and that at 72 degrees F. The wine fermented at 90 degrees F, however, was definitely disliked by the panelists. This could be due to the rapid deterioration of the whey at that temperature. In the interest of energy conservation, fermenting whey wine at room temperature appears to be the most desirable.

Nutrients

Nitrogen as a yeast nutrient was supplied by a mixture of 50 percent ammonium phosphate and 50 percent ammonium chloride. This mixture was tested at concentrations of 500 and 1,000 parts per million.

Table 1. EFFECT OF YEAST STRAINS ON FERMENTATION RATE

Yeast strain	Time for completion of fermentation, days	Fermentation rate, days^{-1}	Alcohol production, %
Montrachet	7	0.14	10.35
Champagne	8	0.13	10.25
Sherry	8	0.13	10.00
Port	12	0.08	10.20
Burgundy	14	0.07	10.10

Table 2. EFFECT OF TEMPERATURE ON FERMENTATION RATE

Temperature, °F	Time for completion of fermentation, days	Fermentation rate, days^{-1}	Alcohol production, %
55	17	0.06	10.65
72	7	0.14	10.51
90	4	0.25	10.20

Vitamins B_1 (thiamin) and B_2 (riboflavin), known also to increase the efficiency of yeast fermentation, were tested at 5 parts per million, respectively. The results in Table 3 show that the addition of yeast nutrients was not found to be necessary for fermentation of whey wine. Neither the fermentation rate, nor the percentage of alcohol produced was increased significantly. It appears that the whey itself contains sufficient nutrients for yeast growth, and additional nutrients are of no value.

Preservatives

Sulfur dioxide and sorbic acid were tested as preservatives for whey wine. The effectiveness of the preservatives was determined by plate counts of viable microorganisms at different time intervals. Results are shown in Table 4. After nine weeks, some samples had coents of a few hundred microorganisms per milliliter. These are considered as low counts for wine. All the wine samples had a decrease in counts at subsequent intervals. At the end of 19 weeks, all samples are virtually sterile, including the control. Evidently, the combined preservation effect of alcohol and lactic acid present in the wine offers sufficient protection for dry whey wine, and no chemical preservatives are needed. Wine treated with 100 parts per million SO_2, however, seems to have a cleaner taste and perhaps would be a desirable practice. Sorbic acid treated wines exerted some effect on the flavor of the wine. The degree of off-flavor was in proportion to the preservative concentration.

Clarifying Agents

To make clear whey wine, bentonite has shown promise as a clarifying agent as shown in Table 5. This clarifying agent, when used in a concentration of 0.5 percent, showed excellent results for clarifying cloudy whey wine. It was observed that de-proteinized whey produced cloudy whey wine, due to the activity of the yeast.

Sparkolloid (a trade name for a polysaccharide product) and casein were found to be poor clarifying agents for whey wine. Adjusting the pH of the wine with potassium carbonate to the iso-electric point of whey protein (pH 5.1 to 5.3) facilitated protein precipitation. The problem here, however, is that at the iso-electric point, the wine is low in acidity, and tastes flat.

Tannin appears to be a good clarifying agent, except that it may impart an off-flavor to the wine. Its use is presently undergoing further study.

Table 3. EFFECT OF NUTRIENTS ON FERMENTATION RATE

Nutrient	Time for completion of fermentation, days	Fermentation rate, days^{-1}	Alcohol production, %
Control	7	0.14	10.3
250 ppm $(NH_4)_2HPO_4$ + 250 ppm NH_4Cl	8	0.13	10.2
500 ppm $(NH_4)_2HPO_4$ + 500 ppm NH_4Cl	7	0.14	10.1
5 ppm Vitamin B_1	8	0.13	10.1
5 ppm Vitamin B_2	8	0.13	10.3

Table 4. EFFECT OF PRESERVATIVES ON VIABLE MICROORGANISMS IN WHEY WINE

Preservative	Plate counts (colonies/ml) after:			
	9 weeks	12 weeks	15 weeks	19 weeks
Control	800	110	4	0
SO_2, 50 ppm	1,300	58	9	3
SO_2, 100 ppm	8	1	1	0
SO_2, 200 ppm	0	0	0	0
SO_2, 300 ppm	0	1	0	0
Sorbic acid, 100 ppm	400	135	1	1
Sorbic acid, 200 ppm	18	0	1	2
Sorbic acid, 300 ppm	30	167	9	0
Sorbic acid, 400 ppm	0	0	-	-

Table 5. EFFECTIVENESS OF CLARIFYING AGENTS FOR WHEY WINE

Clarifying agent, %	Clarifying action			
	Poor	Fair	Good	Excellent
Bentonite				
0.20	X			
0.25		X		
0.30			X	
0.50				X
Sparkolloid, cold				
0.01-0.20	X			
Casein				
0.01-0.20	X			
Tannin				
0.010	X			
0.015		X		
0.020			X	
K_2CO_3				
0.44			X	
0.48				X
0.52			X	

Cloudy and clear whey wines were compared by gas-liquid chromatography. The instrument used was a Varian Aerograph 1200 with a hydrogen flame ionization detector. Samples of whey wines were injected directly.

The column used was a 12 foot by 1/8 inch stainless steel packed with 5 percent BDS (butanedial succinate) and 0.05 percent igepal on Chromosorb G. The column was conditioned at 170 degrees C and maintained at 135 degrees C. The range was set on 1 and the attenuation was 128. The nitrogen flow was 20 milliliters per minute, the sample size was 10 microliters, and the chart speed 20 inches per hour.

Typical gas chromatographs are reproduced in Figure 2. It is seen that both the cloudy and the clear whey wines produced identical chromatograms, indicating that the volatile components present in the whey wine were retained after clarification. Peak 2 of the clear wine, however, is lower than that of the cloudy wines, indicating that perhaps some loss of this component may have occurred during fining and filtering.

No attempt has been made at this point to identify the chemical compounds represented by the peaks on the chromatograms. It is anticipated that this will be done in the future, in conjunction with the investigation of the smaller peaks and their significance in the total flavor of the whey wine.

Fruit-Whey Wines

The possibility of blending fruit and berry wines with whey wine was investigated. Raspberry, strawberry, blackberry, apple, and pear wines were prepared according to methods prevailing in the Pacific Northwest.[7] Each fruit or berry wine was blended with whey wine on a 50-50 basis. All the berry blends of whey wine were considered acceptable in the flavor preference tests that were conducted (Table 6). The apple and pear blends were not considered acceptable. This is probably because these two fruits are generally weaker in flavor, as compared to the berries.

Flavored Whey Wines

The possibility of flavoring whey wine with synthetic flavors was investigated. Citrus, cola, and raspberry flavors were evaluated. The cola-flavored wine left a medicinal after-taste, and was not acceptable. A 50-50 blend of whey wine and Coca-Cola, however, was a more acceptable product. The raspberry-flavored whey wine was not comparable to the

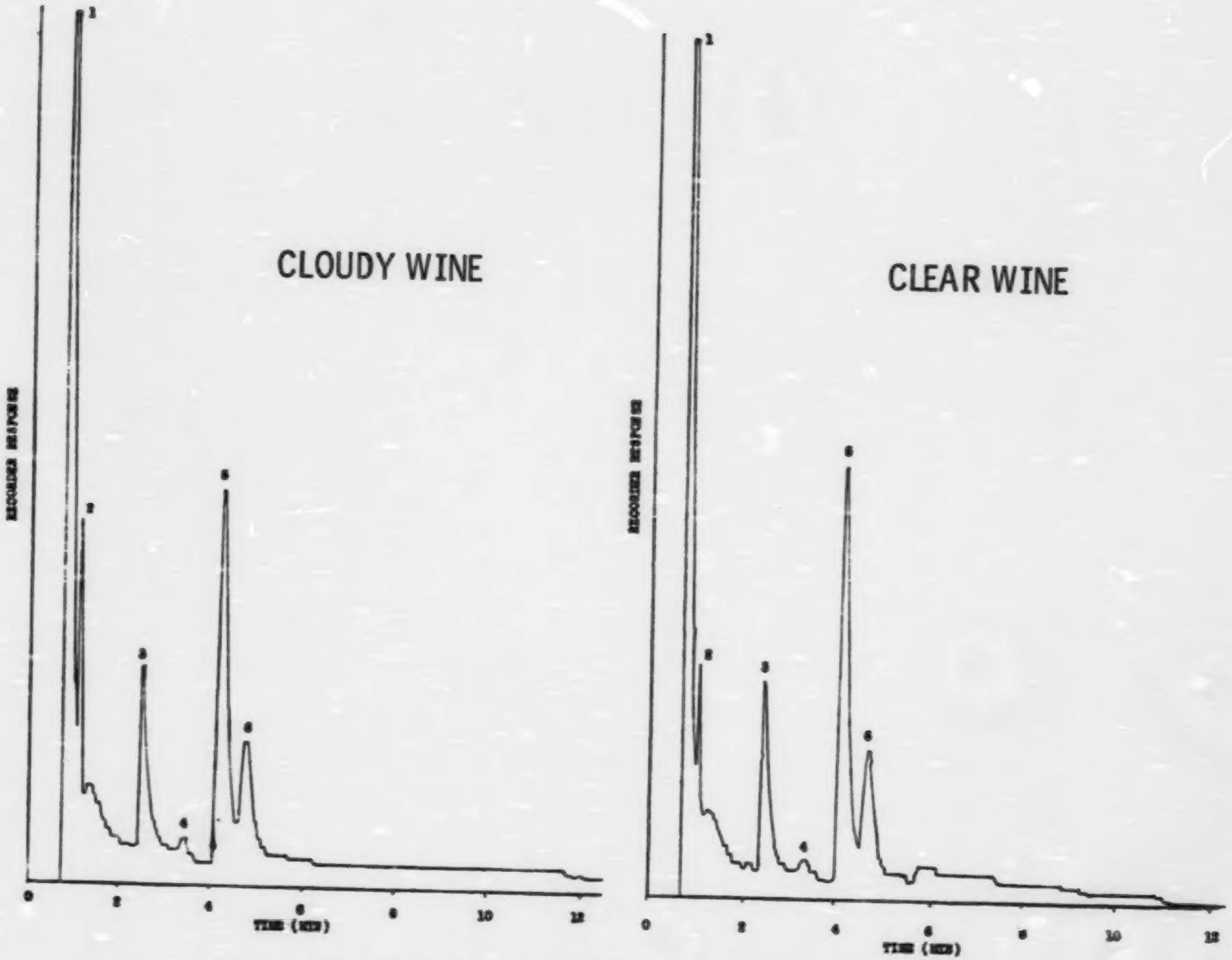


Figure 2. Gas chromatograms of whey wine.

natural raspberry-whey wine blend previously tested. The flavored raspberry wine tasted "synthetic", without the aroma of true raspberry. The citrus-flavored whey wine was considered the best product of the three flavored wines tested. The product has a pleasing taste, which resembles some citrus-flavored pop wines currently selling on the market.

Carbonation

Carbonation was attempted on the flavored whey wines. When a wine was carbonated to a pressure of 2.3 volumes of CO_2, it had a nice head when poured, with bubbles in the glass. Testing of a commercial beer and Coke for pressure gave 2.3 volumes of CO_2 for beer and 3.3 for Coke.

Acceptance

Whey wine, fruit and berry blends, and citrus-flavored wine were submitted for sensory evaluation by Oregon State University personnel, the dairy industry, and other groups. A hedonic scale of 1 to 9 was used for scoring. A score of 5 implies the sample is neither desirable nor undesirable. A mean score of 5 generally indicates the sample is desirable. The higher the score, the higher the desirability. Any score below 5 is rated undesirable.

Table 6 shows the results of the sensory evaluation tests conducted. It is seen that, with the exception of clear dry whey wine and the apple and pear blends, all wines were rated with a relatively high degree of preference by the panelists. The raspberry-whey blend received the highest rating of 6.9. Clear dry whey wine was rated the lowest, 3.8, with apple and pear blends rated just below the neutral point of 5.

One special wine tasting was conducted with a large group during the 1975 Oregon Dairy Industries Conference. A sweetened clear whey wine and a sweetened raspberry-whey wine were submitted to the group of over 300 people for tasting. One hundred and seventy-seven persons completed ballots. The results are summarized in Table 7. It is noted that the majority of the participants liked the clear whey wine or the raspberry wine blend. Only 7 out of the 177, or approximately 4 percent of those tasting, disliked both samples.

It should be noted that the wine samples were evaluated by a different number of varied groups of people in some cases. While the results may serve as an indication of the relative degrees of preference

Table 6. RESULTS OF SENSORY EVALUATION TESTS FOR VARIOUS WHEY WINES

Wine type	Number of panelists	Mean score
Whey, cloudy, sweetened	109	5.2
Whey, clear, dry	36	3.8
Whey, clear, sweetened	145	6.3
Raspberry-whey, sweetened	126	6.9
Strawberry-whey, sweetened	25	6.4
Blackberry-whey, sweetened	25	6.4
Apple-whey, sweetened	25	4.6
Pear-whey, sweetened	25	4.7
Whey, citrus-flavored, sweetened	50	5.5

Table 7. FLAVOR PREFERENCE EVALUATION BY OREGON DAIRY INDUSTRY GROUP

Flavor evaluation statement	Ballot count	Preference, %
"I like the raspberry-whey wine"	123	69.5
"I like the clear whey wine"	47	26.6
"I like neither"	7	3.9

for the products, large scale consumer acceptance tests of each product must be conducted.

EXPERIMENTS IN PROGRESS

Experiments now in progress include the possibility of developing a whey beer, stability tests of wine under various storage conditions, packaging of whey wine, and production of wine from acid (cottage cheese) whey.

SUMMARY

Among the wine yeast strains tested, Montrachet was found to be the most desirable for whey wine fermentation. With this yeast, fermentation can be carried out at room temperature satisfactorily. Yeast nutrients, such as nitrogen and B-vitamins, show little help in increasing the rate of fermentation. It appears that the whey itself contains sufficient nutrients for yeast growth, and additional nutrients are of little or no value.

Chemical preservatives, such as sulfur dioxide and sorbic acid, are not needed for dry whey wine. Evidently, the combined preserving effect of alcohol and lactic acid present in the wine offers sufficient protection. Wine treated with 100 parts per million SO_2, however, seems to have a cleaner taste, and perhaps would be a desirable practice.

To make clear whey wine, bentonite has shown promise as a clarifying agent. Cloudy and clear whey wines were compared by gas-liquid chromatography, and both wines produced identical chromatograms, indicating that the volatile flavor components present in the whey wine were retained after clarification.

Whey wine was also blended with fruit and berry wines to produce fruit-whey wines. It was also flavored with synthetic flavors and carbonated to produce effervescent, flavored, whey wine.

Flavor preference test results show that a great majority of the panelists liked, in various degrees, one or more of the whey wine preparations. The favorites of the panelists were clear sweetened whey wine and whey wine blended with berry wines, especially raspberry-whey wine.

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DRY PEELING OF TOMATOES AND PEACHES

Traver J. Smith*

INTRODUCTION

For many years Magnuson Engineers has been developing and manufacturing machinery for peeling fruits and vegetables for the canning, freezing and dehydration industry. In recent years, this effort has been directed toward dry peeling because of the demand to reduce the water pollution which has traditionally been associated with fruit and vegetable peeling. A particular effort has been made to provide equipment which is self-amortizing through savings in labor, increased yield, and reduced waste water treatment costs.

DRY PEELING SOFT FRUITS AND VEGETABLES

Included in this effort has been the development of the soft fruit MAGNUSCRUBBER unit which is designed to gently remove the peel from soft fruits and vegetables without use of water and to collect the peel waste residue and keep it out of the processing plant waste water effluent. This is done by collection, haulage, and separate disposal of concentrated peeling wastes. The principal application of these machines has been for peeling tomatoes and peaches. During the just completed 1974 season, many of these machines were operating in production operations throughout the United States. Some machines have completed three seasons of operation. The soft fruit MAGNUSCRUBBER unit has also been used successfully for peeling apricots, pears, and cooked beets.

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Equipment Description

To gently wipe away softened peel, the machine uses very thin soft rubber discs developed by Mr. Robert Graham of the Western Regional Research Center in Albany, California.[1] In Mr. Graham's original machine, he placed these discs on rotating cylindrical rolls arranged side-by-side to form a flat bed. The product moved across the bed from roll to roll in a direction perpendicular to the roll axis and parallel to the disc surfaces. It utilized a displacement type feed. That is, incoming produce displaced the product already on the bed and caused it to move across the rolls. This machine was first demonstrated in 1970 on apricots and peaches.

Initial Test

During the following processing season, 1971, Magnuson Engineers modified a standard MAGNUSCRUBBER machine of the type which was then already widely in use for peeling root vegetables, by installing the Graham soft rubber discs. In this machine and in subsequent production machines, the rotating rubber disc rolls are assembled in a circular revolving cage containg a feed screen through the center. The product flow is at right angles to the Graham unit. In this machine the fruit moves parallel to the roll axis and perpendicular to the surfaces of the roll discs. This gives more complete envelopment of the product within the soft moving disc surfaces, providing gentle, thorough scrubbing much like wiping the fruit with the palms of the hands. The feed rate is accurately controlled by the central screw conveyor.

For a high volume production machine, the disc roll arrangement of the MAGNUSCRUBBER has proved to provide much more effective and controllable peel removal than can be obtained with the flat bed type unit.

PEACH PEELING

With minor exception, peaches are always pitted as the first step in the processing operation. All pitting machines cut the fruit in half while removing the pit. Consequently, the peeling process must be applied to pitted peach halves. These are mechanically placed on a conveyor in a "cup down" position (peel upwards) and a hot caustic solution of 1 to 3 percent sodium hydroxide is cascaded over them, exposing only the upper skin surface to the caustic action. Later, on the same conveyor, they are sprayed with jets of water to flush away the caustically disintegrated peel as finely dispersed particles. This process, of course, produced large volumes of waste water containing caustic combined with peach solids, both suspended and dissolved.

In 1971, this first experiment disc roll type MAGNUSCRUBBER unit was demonstrated for peeling clingstone peach halves.[2] The product was peeled with thorough skin removal, the corner of the half at the cut surface remained sharp and peach halves had high quality appearance. The machine was run at capacities above 20 tons per hour and the demonstration was considered successful. The same season, a machine of the flat bed type was also tested and reported by the US Environmental Protection Agency.[3]

Because these machines were run in test situations where they were carrying only a portion of the plant production, they were necessarily operated side-by-side with conventional water spray peeling. It was, therefore, necessary to provide sufficient caustic treatment of the fruit to assure that the fruit processed in the spray washers would be completely peeled. Since the rubber disc peeling process is more vigorous in its action, the peaches peeled by this method experienced a 2 percent higher peel loss. This report of higher peel losses quickly circulated through the peach processing industry and caused the processors to be very apprehensive because of the added cost of these higher losses. It has since been demonstrated with the MAGNUSCRUBBER machine that it is only necessary to reduce the caustic treatment of the peach halves to obtain very high quality peeling with equal or less peel losses that are obtained by the conventional water spray method. In addition, there is reduced caustic consumption which provides lower operating costs.

Interestingly, the more effective scrubbing action provided by the MAGNUSCRUBBER machine produces a labor saving in processing freestone peaches. Freestones are fragile and subject to bruising in growth and handling. These bruises leave surface defects which are visible after peeling and hand labor is required to remove them. The wiping action of the rubber discs removes many of these defects and thus reduces the hand labor. As a result, several machines have been installed for peeling freestone peaches, giving the double advantage of reduced labor cost and reduced waste water treatment cost.

TOMATO PEELING

Immediately following the 1971 demonstration on cling peaches, the disc equipped MAGNUSCRUBBER unit was moved to a tomato processing plant which was operating after the close of the peach season. There it was established that the machine would also very effectively peel caustically treated tomatoes.

Tomatoes peel very differently than peaches. Much stronger caustic solutions are required (16 to 20 percent) and caustic-compatible wetting agents must be used. While the tomato surface beneath the skin is attacked by the caustic, the skin itself remains intact and comes off in sheets of tissue. Other types of tomato peelers have difficulty in thoroughly removing this peel tissue which tends to transfer from tomato to tomato or from tomato to equipment and back to another tomato. Water sprays are generally used to try to flush away these skins and hand labor is required to finish the skin removal.

In the evolution of the MAGNUSCRUBBER machine for tomatoes, it has been possible to remove substantially 100 percent of the peel at capacities of 8 to 10 tons per hour without using any wash water at all. This has eliminated nearly all the hand labor required to remove peel. About one gallon per minite of lubrication water is used in the machine.

BOD REDUCTION

In both the tomato and peach peeling application, the MAGNUSCRUBBER unit collects and delivers a full strength essentially undiluted peel waste sludge. Since in these operations peel waste is a principal source of biological oxygen demand (BOD) in waste waste treatment, it is highly desirable to keep this peel waste material out of the plant waste water. A 1974 study* indicates that peel wastes accounted for 60 percent of the total plant BOD load in a peach cannery and 35 percent of the total BOD load in a tomato cannery. The plants studied were generally typical of California processing methods. Food processors now recognize that it is very expensive to remove a BOD load from waste water, both in terms of the plant investment for waste water treatment facilities and its operating cost. It is now widely acknowledged that it is much better to prevent these wastes from entering the plant effluent and thus avoid the cost of waste water treatment. This is especially true in seasonal operations where expensive waste water treatment facilities will be used for only two or three months per year.

INCREASED PRODUCT RECOVERY

During the 1974 season, a California processor who was using four MAGNUSCRUBBER machines for dry peeling of tomatoes reported an increased product removery of 2-1/2 cases per ton which was attributed entirely to the reduced product losses made possible by the MAGNUSCRUBBER units. This plant also showed a 44.7 percent reduction in caustic consumption. Such savings are possible because the mechanical wiping action of rubber discs permits less caustic exposure of the tomatoes which reduces the product losses in the caustic solution. Similarly, since water washing is not used during peel removal, this eliminates the loss of tomato solids which are normally carried away by the waste water.

PRODUCTION PROCESSING RESULTS

To make an accurate comparison between water wash peel removal and dry peel removal, a detailed study was made in three canneries during the 1974 peach and tomato processing seasons. The study was made by CH_2M-Hill and the data in the following tables has been extracted from their report.[4]

CONCLUSION

From the tables presented, it is very apparent that the MAGNUSCRUBBER machine provides very substantial reductions in water usage, BOD, COD, and suspended solids in both peach and tomato canning operations. These reductions are increasingly necessary in these processes to meet demands for reduced water pollution.

Now that the mechanics of dry caustic peel removal are proven and in production, much attention is focused on the handling and disposal of peel waste sludge. So far, this material has been hauled from the plant site in tank trucks and disposed of by spreading on land; sometimes on pasture land where cattle are feeding. In one circumstance, where a plant had traditionally been discharging peeling wastes into a river until prohibited, the peel sludge was hauled 35 miles and dumped into a city sewer, paying sewage charges. Obviously, better solutions that are required.

So far, spreading on land is the only acceptable method for disposal of peach peel waste. As this material becomes available in greater quantities, probable uses for it will be found. Brandy manufacture is a possibility.

Tomato peel waste offers a real promise as a by-product. The peel waste material has a higher solids content than pureed whole tomatoes, because it is made up entirely of material from the outer cells walls of the tomatoes. This is the most highly colored portion of the tomato, so

Table 1. PROPERTIES OF PEEL WASTE SLUDGE AS PRODUCED BY MAGNUSCRUBBER

Property	Peach peel waste	Tomato peel waste
Solids content, %	9-10	7-8
Weight, lbs/gal.	8.5	8.5
pH	13-14	13-14
Color	Dark brown	Bright red
Texture	Like pureed apple sauce. Flows sluggishly.	Like tomato puree with many skins. Flows easily.

Table 2. CAUSTIC PEELING OF PEACHES. REDUCTION OF PEELING WASTES WITH MAGNUSCRUBBER

Parameter	Peel removal method per 1,000 lbs of canned peaches		Reduction with MAGNUSCRUBBER
	Spray washer	MAGNUSCRUBBER	
Water flow	694 gals.	13 gals.	98%
Biological Oxygen Demand	8.6 lbs	0.3 lbs	97%
Chemical Oxygen Demand	12.6 lbs	0.9 lbs	93%
Suspended solids	2.3 lbs	0.2 lbs	91%

Table 3. CAUSTIC PEELING OF TOMATOES. REDUCTION OF PEELING WASTES WITH MAGNUSCRUBBER

Parameter	Peel removal method per 1,000 lbs of canned tomatoes: Water Washing	Peel removal method per 1,000 lbs of canned tomatoes: MAGNUSCRUBBER	Reduction with MAGNUSCRUBBER
Water flow	604 gals.	14.5 gals.	98%
Biological Oxygen Demand	6.0 lbs	2.4 lbs	60%
Chemical Oxygen Demand	10.2 lbs	3.1 lbs	70%
Suspended solids	2.2 lbs	0.5 lbs	77%

Table 4. PEACH CANNING. REDUCTION OF TOTAL PLANT WASTES WITH MAGNUSCRUBBER

For total plant	Peel removal method per 1,000 lbs of canned peaches: Spray washer	Peel removal method per 1,000 lbs of canned peaches: MAGNUSCRUBBER	Reduction with MAGNUSCRUBBER
Water flow	1,470 gals.	789 gals.	46%
Biological Oxygen Demand	13.6 lbs	5.3 lbs	61%
Chemical Oxygen Demand	25.2 lbs	13.5 lbs	46%
Suspended solids	6.5 lbs	4.4 lbs	32%

Table 5. TOMATO CANNING. REDUCTION OF TOTAL PLANT WASTES WITH MAGNUSCRUBBER

For total plant	Peel removal method per 1,000 lbs of canned tomatoes: Water washing	Peel removal method per 1,000 lbs of canned tomatoes: MAGNUSCRUBBER	Reduction with MAGNUSCRUBBER
Water flow	3,750 gals.	2,690 gals.	28%
Biological Oxygen Demand	49.3 lbs	31.4 lbs	36%
Chemical Oxygen Demand	93.2 lbs	44.5 lbs	52%
Suspended solids	45.3 lbs	-	-
pH of water waste	9.4	6.2	-

this material is very high in desirable red pigment. Of course, the material contains caustic (NaOH), but this can be neutralized with hydrochloric acid (HCl) and converted to common table salt (NaCl) and water. Salt is ordinarily added to tomato products for flavor anyway. This project will be the subject of another paper at this seminar. It's enough to say that it is very likely that the tomato peel fraction can be processed into high quality tomato products for human consumption.

This would provide greatly increased produce recovery and would eliminate 75 percent of the waste disposal problem. Could there be a better pollution solution than that?

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A FRUIT PROCESSORS WASTE TREATMENT EFFLUENT VARIABILITY AND PLANNING FOR ATTAINMENT OF 1983 EFFLUENT GUIDELINES

Larry A. Esvelt*

INTRODUCTION

Snokist Growers, a cooperative, operates a fruit cannery at Yakima, Washington. In 1966 the cannery began construction of a wastewater treatment system and was assisted by a research and development grant from the Federal Water Pollution Control Administration, now the US Environmental Protection Agency (EPA). Their wastes were treated in a newly constructed aerated lagoon system during the 1967 processing season which was upgraded to a complete mixed activated sludge system with capability for limited sludge reaeration by the 1968 processing season. The results of the research and development study connected with the treatment system indicated that biological treatment was feasible for fruit processing wastes.[1,2] Biological oxygen demand (BOD) removals by the complete mixed activated sludge system, with nutrient addition, exceeded 99 percent during the 1968 processing season. Biological uptake rate and sludge growth parameters were developed during the research and development study to allow application of the treatment system at other locations.

The Water Pollution Control Act Amendments passed by Congress in 1972 directed that industries provide Best Practicable Treatment of wastewaters by 1977 and employ Best Available Treatment technology by 1983. EPA, the administering agency, subsequently contracted with consultants to develop effluent limitation guidelines for compliance with this directive. Snokist Growers wastewater treatment system was cited as producing an exemplary effluent in the development of guidelines for peach, pear and apple processing industries.[3,4]

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The purpose of this paper is to discuss Snokist's wastewater treatment facility, its adequacy to date and its anticipated adequacy based on the guidelines for effluents developed by the EPA. This paper will also discuss planned improvements by Snokist Growers to attain 1983 levels of best available treatment for their cannery effluent.

WASTEWATER TREATMENT FACILITIES

The wastewater treatment facilities completed for Snokist Growers' Cannery in 1968 consist of a six million gallon aeration basin with surface aerators totaling 390 horsepower. The aeration basin is coupled with a 90-foot diameter secondary clarifier and sludge recirculation capacity of 2.5 million gallons per day for normal operation and 5 million gallons per day peak capacity. A 1.5 million gallon aerated lagoon with two 30 horsepower surface aerators is used for activated sludge reaeration and provides the overall system with approximately 50 percent greater solids capacity. A flotation sludge thickener was constructed in 1968 to allow thickening of the waste activated sludge for wasting by hauling to landfill or land application.

The wastewater treatment system for Snokist Growers has performed satisfactorily since 1968 with a few exceptions. During one processing season, in-plant chlorination of a cooling water supply became excessive which upset the treatment system a number of times before the problem was identified and a remedy initiated. During another season nutrient feed problems caused upset conditions during a portion of the year. Otherwise the biological treatment portion of the plant has easily provided adequate treatment but the solids wasting capacity has been inadequate during several seasons which allowed the solids in the biological system to build up and spill over into the effluent for short periods.

The production of excess solids has increased since initial startup of the wastewater treatment system due to increased processing rates and increased wasteloads. Figure 1 shows the average daily processing rate for pears, peaches and apples that have been maintained throughout the processing season since 1966. Pear processing and apple processing, which are the principal cannery activities, have each steadily risen since that time. The 1974 processing season has seen an additional problem arise when the energy shortage caused a threat of natural gas delivery cut-back in the event of a severe winter which in turn necessitated concurrent processing of apples and pears during the earlier fall period. The result of the increased processing rate can be seen on Figure 2 where the average COD discharge rate from the cannery to the treatment system during the maximum processing month for each of

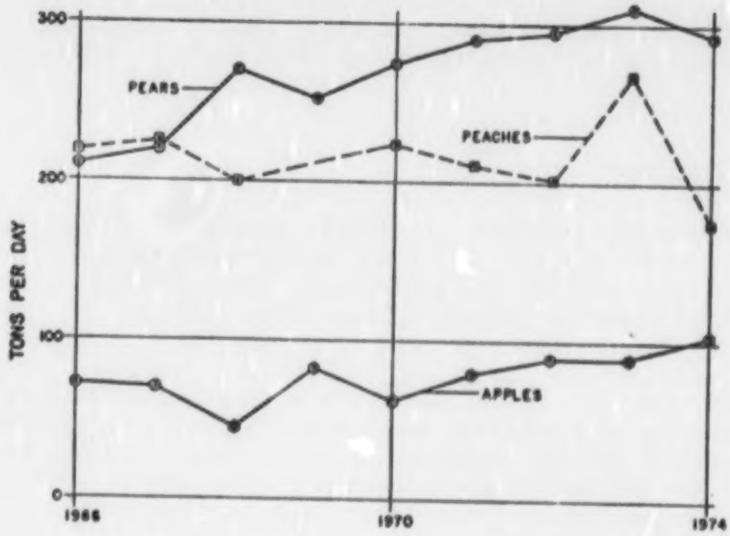

Figure 1. Processing rates - 1966 to 1974 Snokist Growers' Terrace Height Cannery.

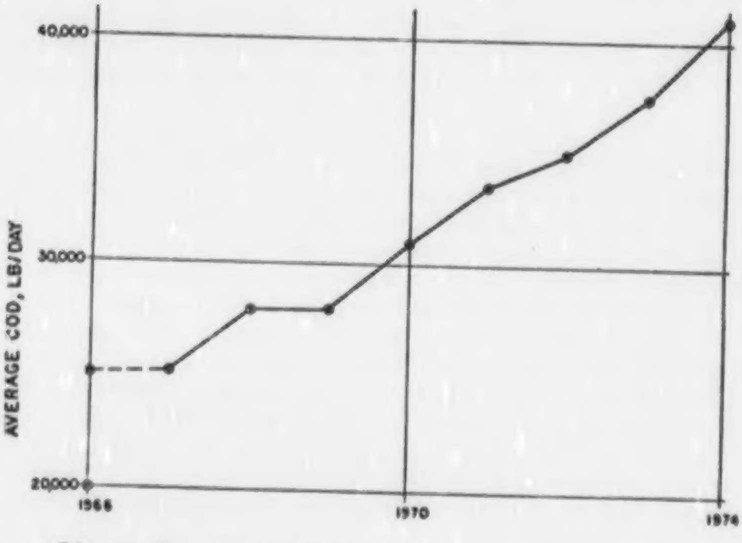

Figure 2. COD effluent to treatment system.

the years is shown. The effect of concurrent processing of apples and pears in 1974 is also quite evident on this chart.

The fixed volume and aeration capacity of the treatment system causes increases in loading rate on the treatment system to result in disproprotionately larger increases in excess solids that must be disposed of. The total biological solids in the system is limited by solids consolidation rate in the clarifier and aeration volume which holds endogenous respiration at a relatively constant level, while conversion of the BOD and COD to solids increases linearly and results in a marked increase in the net solids increase as shown in Figure 3. The excess solids must be wasted or escape in the effluent.

The solids wasting system consisting of the sludge thickener and accompanying pumps is marginally adequate when all facilities are in good operating condition. The thickener increases the solids content to only approximately 2.5 percent total solids on a consistent basis instead of the 4 percent that was originally hoped for. This creates a situation where an excessive amount of water must be hauled away with the waste activated sludge solids. Any malfunctions of pumps, recirculation system, or other portion of the sludge wasting system results in the inability to waste sludge solids and usually results in the loss of solids to the effluent.

EFFLUENT LIMITATIONS GUIDELINES

Effluent limitations guidelines were first developed for the apple, potato and citrus industries of the point source food processing category[3] by a subcontractor for the EPA who used data from existing facilities coupled with data collected during the development of the guidelines to determine the Best Practicable Control Technology Currently Available (BPCTCA). A later study by another subcontractor[4] resulted in development of BPCTCA for the other commodities within this point source category. BPCTCA was based on assumptions of (1) activated sludge or aerated lagoon biological treatment for BOD removal, (2) aerated lagoon treatment for total suspended solids (TSS) removal, and (3) the ratio of average daily effluent to maximum day effluent taken from activated sludge plants. The resulting BPCTCA guidelines applicable to Snokist Growers are shown in Table 1.

The contracts awarded by EPA for development of guidelines also resulted in recommended Best Availability Technology Economically Available (BATEA). This technology was based on the assumption of (1) in-plant waste reduction in volume, (2) activated sludge or aerated lagoon treatment for BOD removal, (3) activated sludge or aerated lagoon

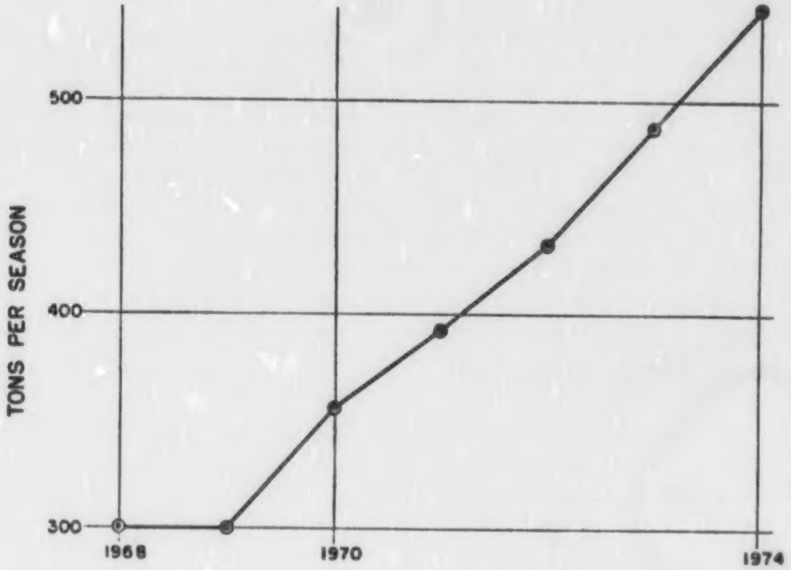

Figure 3. Net biological solids production by treatment system.

Table 1. BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE (BPCTCA)

	BOD kg/kkg (lb/ton)		TSS kg/kkg (lb/ton)	
	Max. Monthly	Max. Daily	Max. Monthly	Max. Daily
Apricots	1.0 (2.1)	2.5 (5.0)	1.7 (3.4)	5.0 (9.9)
Cherries (sweet and sour)	0.9 (1.8)	2.2 (4.3)	1.4 (2.9)	4.2 (8.4)
Peaches	9.5 (1.7)	2.0 (4.1)	1.4 (2.7)	3.9 (7.8)
Pears	1.1 (2.1)	2.5 (5.0)	1.7 (3.4)	5.0 (9.9)
Plums	0.28 (0.56)	0.65 (1.3)	0.45 (0.90)	1.3 (2.6)
Apple products	0.35 (0.70)	1.40 (2.80)	0.45 (0.90)	1.80 (3.60)
Grease and oil	less than 20 mg/l			
pH	within the range 6.0 to 9.0			

treatment for BOD removal, (3) activated sludge or aerated lagoon treatment followed by mixed media filtration for TSS and additional BOD removal, and (4) disinfection for fecal coli removal. BATEA recommended guidelines are shown on Table 2 for products of concern to the Snokist Growers' Cannery.

Utilizing the guideline levels for 1977 and 1973 as presented in the EPA development documents and the rate of production levels indicated on Figure 1, effluent limitations can be developed as they may be included in an NPDES permit using the guideline levels. These are shown for the 1977 and 1983 levels on Table 3 for the principal products at Snokist Growers.

TREATMENT SYSTEM PERFORMANCE

Since Snokist Growers has kept accurate records of their effluent characteristics since 1967, it is possible to look at the historical variability of the effluent in relationship to the 1977 and 1983 guideline levels. Initial examination of the records indicated that it would not be suitable to utilize 1969 and 1971 data as those were the two years when nutrient feeding and chlorination problems upset the treatment system. Therefore, 1972, 1973 and 1974 operating seasons were examined in more detail to determine the extent of compliance with proposed 1977 and 1983 guidelines levels. Table 4 shows an indication of violations of 1977 guideline levels applied to Snokist's processing rate, as in Table 3 during the months of August, September, October, November and December for these three operating seasons. Violations of the daily maximum TSS level occurred during two months in these operation seasons. Violation of the maximum daily BOD occurred during one month, in August, when startup of the system is annually undertaken. The monthly average TSS guideline level was also exceeded during one month in 1974.

Table 5 presents an indication of the frequency of violation of the 1983 guideline level for these same three operating seasons and the same five months of operation. Here the violations are more frequent with TSS monthly average and maximum daily potential limitations exceeded several times during the 1972 and 1974 processing seasons and during one month for each of them during the 1973 season. The proposed BOD limitation was also exceeded during both the 1972 and 1974 processing seasons.

It is not coincidental that the 1973 season shows fewer violations of the proposed 1983 guideline levels than the years 1972 and 1974. During each of the 1972 and 1974 seasons, equipment malfunctions

Table 2. BEST AVAILABLE TECHNOLOGY ECONOMICALLY AVAILABLE (BATEA)

	BOD		TSS	
	kg/kkg (lb/ton)		kg/kkg (lb/ton)	
	Max. Monthly	Max. Daily	Max. Monthly	Max. Daily
Apricots	0.55 (1.1)	1.3 (2.6)	0.55 (1.1)	1.6 (3.2)
Cherries (sweet and sour)	0.38 (0.74)	0.90 (1.8)	0.37 (0.74)	1.0 (2.1)
Peaches	0.36 (0.72)	0.85 (1.7)	0.36 (0.72)	1.0 (2.1)
Pears	0.42 (0.84)	1.0 (2.0)	0.42 (0.84)	1.2 (2.4)
Plums	0.12 (0.23)	0.28 (0.55)	0.12 (0.23)	0.34 (0.67)
Apple products	0.07 (0.14)	0.28 (0.56)	0.10 (0.20)	0.40 (0.80)
Grease and oil	less than 20 mg/l			
pH	to be in the range 6.0 to 9.0			
MPN (fecal)	to be less than or equal to 400 per 100 ml.			

Table 3. SNOKIST GROWERS EFFLUENT LIMITATIONS[a] ACCORDING TO GUIDELINES

Guidelines level, year	BOD	TSS
1977		
Pears at 300 t/day	600/1500	1020/2970
Apples at 100 t/day	70/280	90/360
Peaches at 270 t/day	460/1110	730/2110
1983		
Pears at 300 t/day	250/600	250/720
Apples at 100 t/day	14/56	20/80
Peaches at 270 t/day	195/460	195/570

[a] Monthly average/maximum day, pound/day.

Table 4. VIOLATIONS OF 1977 GUIDELINE LEVEL

Year	Aug	Sep	Oct	Nov	Dec
1972					
BOD					
TSS					Max.
1973					
BOD					
TSS					
1974					
BOD	Max.				
TSS					Avg./max.

Table 5. VIOLATIONS OF 1983 GUIDELINE LEVEL

Year	Aug	Sep	Oct	Nov	Dec
1972					
BOD	Max		Avg.		Avg./Max.
TSS	Max.		Avg.		Avg./Max.
1973					
BOD					
TSS					Avg./Max.
1974					
BOD	Max.				Avg.
TSS	Avg./Max.				Avg./Max.

occurred which precluded the wasting of sludge for a short period during the season, whereas during 1973 it was possible to waste activated sludge throughout the entire season. Because of the ability to waste sludge more consistently during the 1973 season, fewer or practically no violations would have occurred to the 1983 guideline levels, had they been in force, until near the end of the season when even during that optimum year, solids build-up in the system exceeded sludge wasting capacity to the extent that some solids did escape in the effluent and thus exceeded the proposed guideline level. During each of the 1972 and 1974 seasons, the last month of operation resulted in fairly consistent violations of guideline levels as a result of solids buildup and carryover.

Violations during the initial startup phases of the seasons were not due to solids wasting capabilities. These resulted from the imposition of a relatively heavy organic load on the unacclimated biological system. The startup of the system in 1973 was enhanced by the fact that crab apples had been processed in the system shortly preceding the start of pear processing thus allowing an accumulation of a viable activated sludge which more rapidly responded to the increased organic load and would not have resulted in violation of even the 1983 guideline levels for BOD or TSS during pear processing startup. However, the system would have violated pH guideline levels during each of the three seasons when pH of the effluent during startup dropped to below 6.0. It was necessary in each case to buffer the pH in the system with sodium hydroxide in order to prevent the loss of excess solids and to allow a more rapid establishment of the viable biological floc for organic removal.

Compliance with the guidelines for oil and grease are no problem at Snokist Growers since there is no oil or grease utilized in the process. Compliance with the proposed 1983 guideline for fecal coliforms is unknown at this time since equipment for monitoring these parameters was not yet available during the 1974 processing season.

The 1973 processing season being most exemplary for the Snokist wastewater treatment system in recent seasons appeared to be the most logical for comparison with BATEA guidelines to determine the degree of compliance. Table 6 shows that unit emission rate mean and range of one standard deviation based on logarithmic averaging for flow, BOD and TSS for the 1973 processing season. The unit emission rates based on tons of raw product processed allow a comparison of the means achieved with those indicated on Table 2 to ascertain the degree of compliance of this treatment system with the BATEA guidelines. It can be observed from Table 6 that cherry processing results in an emission rate in excess of that indicated under the BATEA guidelines for both BOD and TSS. The emission rate of BOD and TSS for pears and peaches (including plums

Table 6. SNOKIST GROWERS TREATMENT PLANT UNIT
EMISSION RATE - 1973 PROCESSING SEASON[a]

Product	Flow, gal./ton	BOD, lb/ton	TSS, lb/ton
Cherries	11,300	0.66	1.79
(3 weeks)	(8,750-14,600)	(0.44-1.01)	(1.20-2.66)
Crab apples	7,840	0.63	1.29
(1 week)	(6,930-8,880)	(0.53-0.76)	(0.76-2.18)
Pears	4,520	0.25	0.44
(2 months)	(4,060-3,030)	(0.16-0.38)	(0.31-0.63)
Peaches and plums	6,370	0.22	0.55
(1 week)	(5,270-7,100)	(0.14-0.36)	(0.41-0.73)
Apples	6,390	0.37	0.99
(4 months)	(4,360-9,300)	(0.18-0.78)	(0.39-2.50)

[a] Log Mean = Log Mean ± 1 Log Standard Deviation.

which were processed concurrently) both comply with the BATEA guidelines.

Table 6 indicates that the effluent did not comply with the BATEA guidelines during apple processing and in fact the log mean emission rate for the TSS exceeds the proposed maximum daily guideline under BATEA. This points up a problem which must be faced by regulatory agencies in developing effluent limitations from the guidelines presented in the development documents. For a treatment system designed for and treating a relatively heavy load of pollutants during a portion of the processing season, and receiving a reduced pollutant load during processing of other products, the treatment system effluent may contain excessive pollutants on a per ton basis for the other products. This may occur even though the operation of the facility is at its optimum. It is potentially caused by the scale of the facility as opposed to the pollutant load being introduced, residual solids in the system accumulated during the treatment of the earlier, heavier pollutant load and different characteristics of the newly introduced wastes. Colder weather, which would normally be expected to result in poorer treatment performance than during warmer periods would have a relatively greater effect on an over-designed treatment system during treatment of the "minor" products. The development documents did not extensively consider the effect of cold weather on treatment system performance and, thus, the averages utilized to develop BATEA guidelines may be excessively stringent for climatological conditions similar to those where Snokist Growers' Cannery is located, especially if an oversized aeration basin causes temperature effects to increase in severity.

To provide equity among discharges, the effluent limitations developed for NPDES permits should allow for temperature effects on treatment performance, and for startup and product changes, and for carryover of residuals from one product to another. Limitations should be applied to the maximum production rate and maximum waste load generating product and the NPDES permit conditions should call for efficient operation during other processing periods and products.

PLANNING FOR MEETING THE 1983 BATEA GUIDELINES

Snokist Growers presently has two research and development projects underway, each of which might have a substantial effect on their wastewater treatment operations. The two projects are: a study of the feasibility of dewatering the waste activated sludge and utilizing the dewatered sludge as a cattle feeding supplement; and a study of the feasibility of reusing the treated effluent from the activated sludge system, following polishing on multimedia filters and chlorination, inside the cannery as a water supply source. Each project is partially supported by research and demonstration grant funds from EPA; and Mr. James Santroch and Mr. Harold Thompson are project officers.

Utilization of Waste Activated Sludge in a Cattle Feeding Ration

Snokist Growers is working under EPA Grant Number S803307 in studying the feasibility of dewatering waste activated sludge using a basket centrifuge and the utilization of the dewatered sludge in a cattle feeding ration. The study is approximately 50 percent complete and shows considerable promise although the overall economic and final conclusions as to the acceptability of the solids as a cattle feed are not yet evaluated. Any final conclusions must be deferred until the study is completed and the data finalized. To date, the waste activated sludge solids from the sludge thickener are being dewatered in a prototype scale basket centrifuge to approximately 8 to 9 percent dry solids without utilizing any thickening aids or chemicals. Pilot scale centrifuge tests did not indicate that variation in centrifuge speed affected the final product total solids content appreciably. The solids level attained was approximately the same on both the pilot scale and the prototype scale centrifuges which were respectively 14-inch diameter and 30-inch diameter basket machines. The solids dewatering capability attained seems to compare favorably to that experienced utilizing waste activated sludge from potato processing waste treatment system[5] where only up to 7 percent solids were attained using a pilot scale centrifuge.

The solids have been fed to three groups of six steers each in varying proportions of their ration, and a fourth group of six steers is used as a control group. The feeding portion of the study is conducted at the Washington State University Irrigation Agriculture Research and Extension Center in Prosser, Washington. The performance of the steers through the first 84 days on the feed rations is shown on Table 7. It can be seen that there is a possible benefit of the waste activated sludge in the ration at low concentraitons as the weight gain for Ration No. 1 with 2.3 percent dry activated sludge solids appears to be greater than for the control or for the other two rations. Ration No. 2 with 4.6 percent dry solids appears to be approximately the same as the control ration. If the final results show a beneficial effect of the sludge, there may be sufficient value placed on the sludge for its inclusion in cattle feeding rations by commercial feed lot operators. The sludge is approximately 40 percent protein on a dry matter basis.

If the waste activated sludge does have sufficient value for a cattle feeder to underwrite the costs of hauling the sludge away from the treatment facility, dewatering of the sludge could show an economic

Table 7. RESULTS OF WASTE FRUIT PROCESSING ACTIVATED SLUDGE IN CATTLE FEED RATIONS - AFTER 84 DAYS

Animal group	Sludge in ration % D.S.	Weight gain, kg/day (lb/day)
Control	0	1.26 (2.78)
Ration No. 1	2.3	1.44 (3.17)
Ration No. 2	4.6	1.21 (2.67)
Ration No. 3	9.3	1.12 (2.47)

benefit since the present practice of hauling the waste activated sludge in its liquid form at only 2.5 percent solids is a substantial cost to the cannery. Even if the solids are not worthwhile for use as a cattle feed there may be some economic advantage to dewatering in savings in hauling and disposal costs. Similar sludges have been reported beneficial in poultry feed rations at concentrations up to 7.5 percent.[6]

Wastewater Reuse Project

The wastewater reuse project, EPA Number S803280, is presently in its first year during which facilities are being constructed to enable the cannery to reuse up to 1 million gallons per day of treatment effluent inside the cannery as a source of water. The particular uses for which the water will be made are as yet undetermined but investigation of the consistency of water quality will be extensive during the 1975 operating season and the water will be used in pilot studies for washing down equipment, washing floors and gutters, initial fruit transport, utilization for belt wash and as steam generation make-up. Chemical and bacteriological monitoring of the polished effluent will show the consistency of reused water quality and the suitability of the water for potential uses.

Two 8-foot diameter multimedia filters (anthracite, silica sand and garnet), a chlorination system which will include automatic chlorine residual monitoring and control, and reuse pumps have been purchased by Snokist Growers for delivery in May and early June. A contract has been awarded for the construction of a filter and chlorination building and installation of equipment and piping prior to the startup of pear processing for the 1975 season.

Pilot filter studies were planned for the 1974 operating season but the moving up of the apple processing to coincide with pear processing and delays in getting equipment for filtering and laboratory analyses resulted in the processing season terminating approximately the time the pilot filter system was ready for operation. A subsequent softening of the market for canned apple products has resulted in the winter cannery operation being delayed and possibly cancelled for the remainder of this processing season which may result in the pilot filter operation not being undertaken.

If water reuse investigations show success in the 1975 season, a more comprehensive utilization of the polished effluent will be undertaken in 1976 to demonstrate that the effluent quality is suitable for reuse in all processing areas except direct make-up to the product cans, such as in syrups. The most critical quality area for the reuse of water will be that of direct cooling which will be investigated during the 1976 processing season.

Figure 4 shows the wastewater treatment system schematic flow diagram as it presently exists and as it will be added to with the effluent polishing system for wastewater reuse and with the potential solids dewatering system. It is hoped that with these two improvements, the quantity of wastewaters and their contained pollutant load can be reduced to the extent that the effluent will meet 1983 guideline levels consistently and without difficulty. One area not shown on Figure 4 which may be necessary is disinfection of the effluent portion going to the river. It is presently anticipated that reuse of water in the cannery will be only up to approximately 50 percent. However, the capability will be installed for recycle and reuse of the treated effluent up to approximately 80 percent during apple processing should the reused water be acceptable in all processes in the cannery.

ACKNOWLEDGMENT

The data for this paper was supplied by Mr. Herb H. Hart, Laboratory Director at Snokist Growers' Cannery. A portion of the data analysis was provided by Mr. Kenneth Dostal of EPA in Corvallis, Oregon.

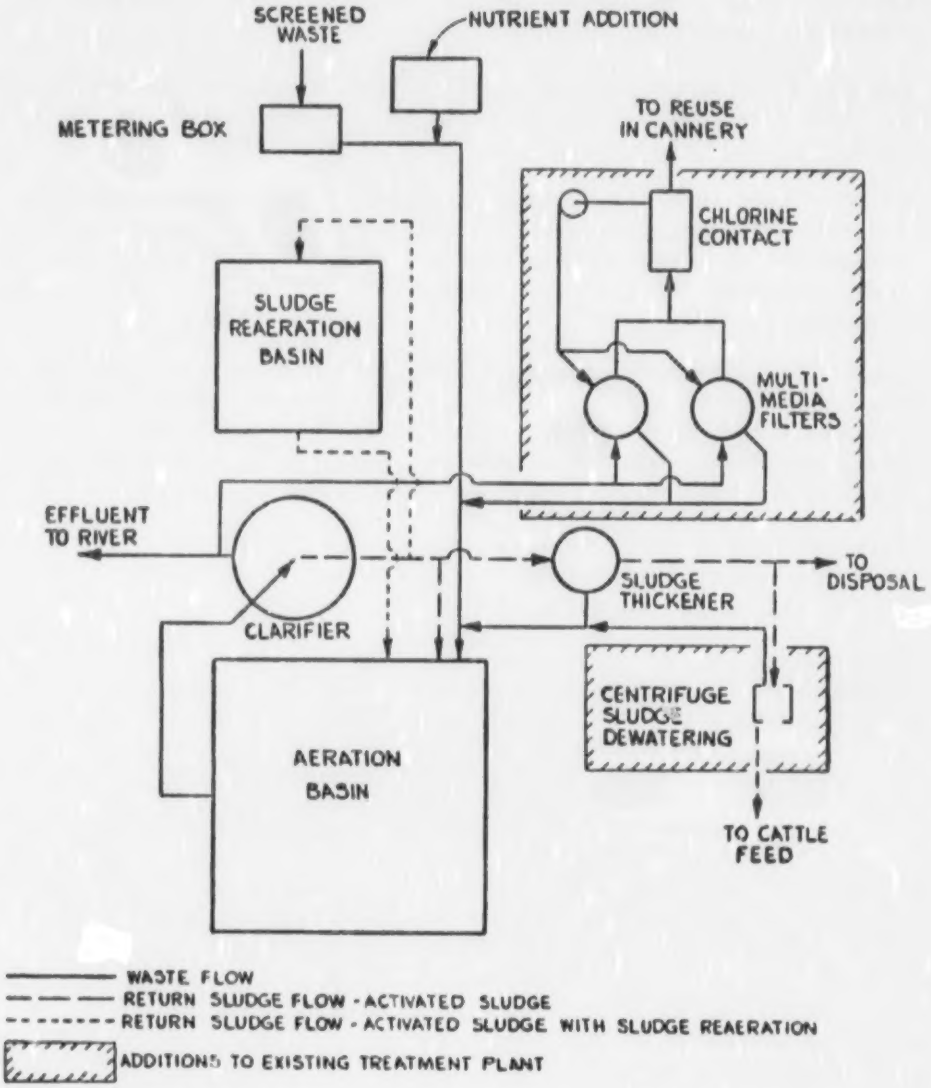
SCREENED WASTE
NUTRIENT ADDITION
METERING BOX
TO REUSE IN CANNERY
CHLORINE CONTACT
SLUDGE REAERATION BASIN
MULTI-MEDIA FILTERS
EFFLUENT TO RIVER
TO DISPOSAL
SLUDGE THICKENER
CLARIFIER
CENTRIFUGE SLUDGE DEWATERING
AERATION BASIN
TO CATTLE FEED
WASTE FLOW
RETURN SLUDGE FLOW - ACTIVATED SLUDGE
RETURN SLUDGE FLOW - ACTIVATED SLUDGE WITH SLUDGE REAERATION
ADDITIONS TO EXISTING TREATMENT PLANT

Figure 4. Wastewater treatment system, Snokist Growers' Cannery.

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TOMATO CLEANING AND WATER RECYCLE*

Walter W. Rose**
Allen M. Kat
George E. Wilson***

Part I: Cleaning of Tomatoes

INTRODUCTION

In 1972, engineers at the US Department of Agriculture's Western Regional Research Center (WRRC), Albany, California, conducted some exploratory tomato cleaning research, using the concept of flexible, spinning rubber discs.[1] This study did indicate that mechanical energy, in the form of rotating discs, could substitute for most of the hydraulic energy, large volumes of water, in cleaning the surfaces of tomatoes. This study also indicated that large numbers of stems could be removed from tomatoes as they were being cleaned.

On the basis of the exploratory work, a cooperative project between WRRC and the National Canners Association (NCA) was carried out in 1973.[2,3] This project evaluated the rubber disc concept for the cleaning and peeling of tomatoes. An integrated pilot scale system was operated at a cannery throughout the 1973 processing season. Data was developed to indicate a substantial reduction in the need for water to clean and peel tomatoes.

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**National Canners Association, Western Research Laboratory, Berkeley, California.
***Eutek Process Development and Engineering, Sacramento, California.

With the cooperation and assistance of an industry ad hoc committee, the NCA prepared a project for consideration by the US Environmental Protection Agency (EPA). The project was designed to demonstrate, on a commercial basis, the cleaning of tomatoes with a rubber disc machine and to develop a water recycle system for dump tank water. Part I of this paper will discuss the cleaning of tomatoes. Part II will discuss the development of a water recycle system.

EXPERIMENTAL PLAN AND PROCEDURE

A tomato cannery was located which processed all of the tomatoes from a single bin dumper. The processor did not receive bulk loads of tomatoes nor did it peel any tomatoes. This was ideal from a project evaluation view-point as it permitted a comparison with the conventional washing system and the proposed demonstration system. The water recycle system was also confined to a single operation and the impact of this on the overall quality of water discharged from the plant could be determined.

Figure 1 is a schematic representation of the processing operations involved in dumping, transporting and washing of tomatoes by the conventional and the demonstration systems. Included in the schematic is an indication of water flows and sampling points.

Prior to startup of the processing season, several changes were made by the processor which significantly altered the amounts of water used in the cleaning of tomatoes. The first and second stage washes were combined into a single flood washer. Water sprays were eliminated from these two operations as well as from the dump tank elevator. A true counter flow system of water was employed. Fresh water was used as a final rinse for tomatoes on the inspection belt. The distribution flume combined first and second stage washes and the dump tank each had independent recirculation loops. The final rinse water co-mingled with the distribution water, with the excess water flowing into the combined washer water. The excess water from this recirculation loop flowed back to the dump tank recirculation system, with the excess water being discharged to the gutter.

On a continual use basis, the final rinse water was the major source of water entering the counter flow system. A secondary source was water used to rinse bins after dumping of tomatoes. This rinse water entered the dump tank and added to the water volume being continually discharged. On an intermittant basis, water to fill the dump tank, inside washer and distribution flume added to the total water used to process the tomatoes. The only other source of water associated

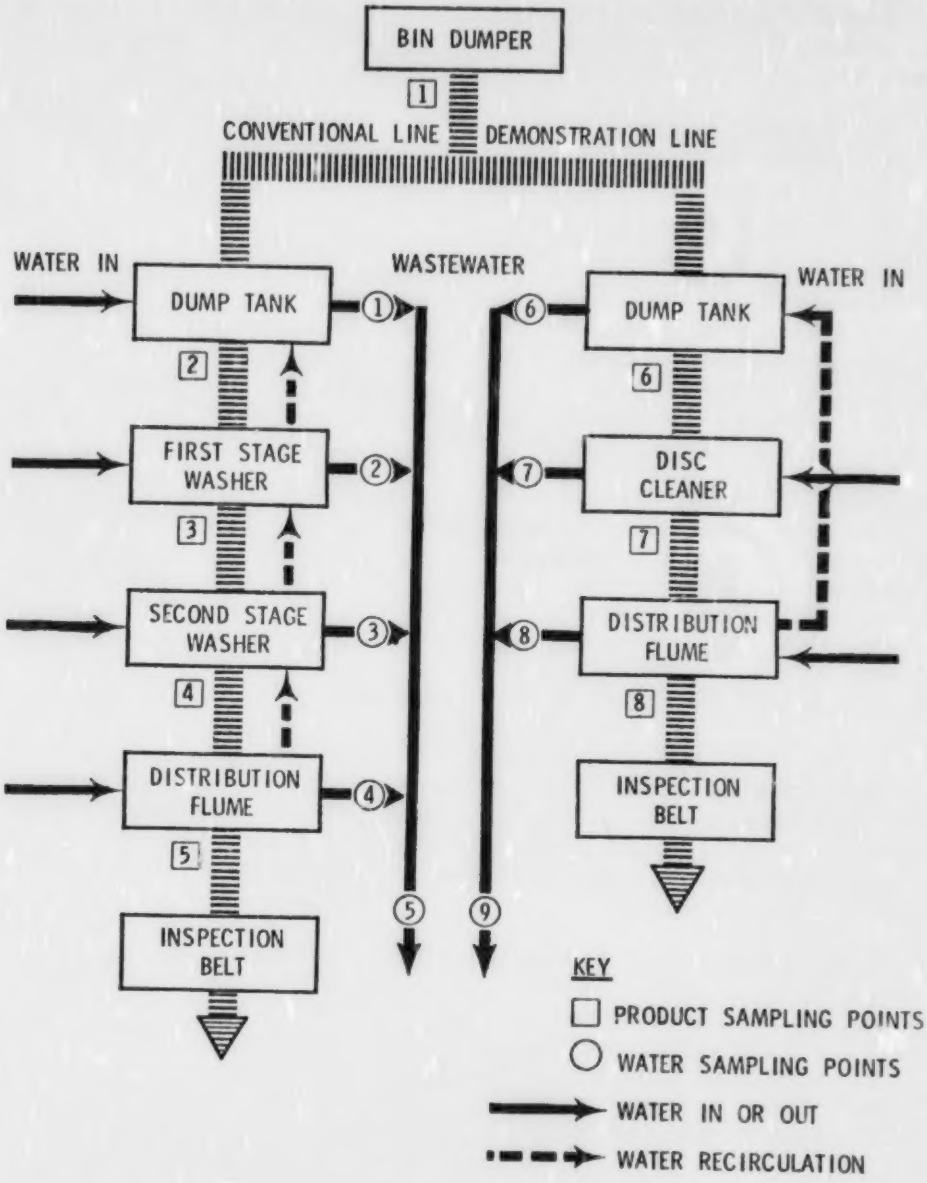
BIN DUMPER
1
CONVENTIONAL LINE
DEMONSTRATION LINE
WATER IN
WASTEWATER
WATER IN
DUMP TANK
①
⑥
DUMP TANK
2
6
FIRST STAGE WASHER
②
⑦
DISC CLEANER
3
7
SECOND STAGE WASHER
③
⑧
DISTRIBUTION FLUME
4
8
DISTRIBUTION FLUME
④
INSPECTION BELT
5
⑤
⑨
INSPECTION BELT
KEY
☐ PRODUCT SAMPLING POINTS
○ WATER SAMPLING POINTS
WATER IN OR OUT
WATER RECIRCULATION

Figure 1. Sampling points for conventional versus demonstration cleaning systems.

with the processing of tomatoes was that used for clean-up purposes either during operations or at scheduled shut downs.

A sampling program was revised to reflect the modifications made by the processor. The product was evaluated for cleanliness by collecting tomato samples from the following locations.

1. Bin before dumping
2. After the dump tank
3. After the combined inside washer
4. After final rinse

Product samples from the demonstration system were collected from the following locations:

1. Bin before dumping
2. After the dump tank
3. After disc cleaner
4. After final rinse

Every 4 hours approximately 5 pounds of tomatoes were collected from the four sampling locations of either the conventional or the demonstration system. After weighing, water equal to twice the weight of tomatoes was added to the tomatoes held in a wire mesh basket that fit inside a plexiglass cyclinder. The tomatoes were shaken for two minutes, then some of the water was transferred to a sterile plastic bag and some to a quart plastic bottle. For each 8-hour period, two of the 4-hour samples were combined, ending up with three 8-hour samples per 24 hours.

All samples were held under refrigeration until transported to the Berkeley laboratory for analysis. Samples in sterile plastic bags were analyzed for total plate count and mesophilic aerobic spores.[4] Samples in the plastic bottles were analyzed for suspended and fixed suspended solids.[5]

Water samples were collected from the following locations:

1. Distribution flume overflow
2. Inside washer overflow
3. Dump tank overflow to gutter
4. Inside collection gutter
5. Disc cleaner effluent

Samples were collected from the above locations on a 24-hour basis with automatic timed samplers. Samples were analyzed for BOD, COD, suspended and fixed suspended solids.[5] Water and product washing samples were collected six days per week. Water meter readings were made during each 8-hour shift.

Figure 2 is a photograph of the disc cleaner. The disc bed is 5 feet wide by 10 feet in length. The bed is inclined upward some 16 inches over the 10 foot length. The discs are mounted on shafts with 3-1/2 inch center. Rotation is by means of a chain and gear arrangement with the initial torque coming to the two front chains. Speed of rotation could be varied but was maintained at 400 revolutions per minute for the duration of the study. Bearings were lubricated by means of an adjustable timed interval system.

Above the disc bin were installed two types of spray systems. One consisted of three evenly spaced manifolds that contained hollow cone or fogging nozzles. The second spray system consisted of four manifolds of flat jet nozzles. The cleaner could be operated with either the hollow cone nozzles for minimal water or a combination of hollow cone and flat jet nozzles. Normal practice was to operate the sprays at 40 pounds pressure.

RESULTS

The initial test phase of the program was to collect data from the disc cleaner and the conventional washing system for comparative purposes. For two days, the disc cleaner was operated over short periods of time with several tomato samples being collected. During these two days, several samples were also collected from the conventional washing system. For some of the runs, the cleaner operated with only the low water hollow cone nozzles and for other runs a combination of the two sprays was utilized.

A summary of the results for this test phase is given in Table 1. Results are given for fixed suspended solids and mesophilic aerobic spores, two indicators of the cleanliness of tomatoes.

Results in Table 1 for the disc cleaner indicate the importance of supplementing the mechanical energy of the rotating discs with some water. Results from the cleaner are much better when operated with a combination of sprays rather than with the mist type hollow cone nozzles.

Results for the final rinse of the conventional system did give the best results. However, this could be expected as tomatoes are in contact with water for a longer period of time. Also, the volume of

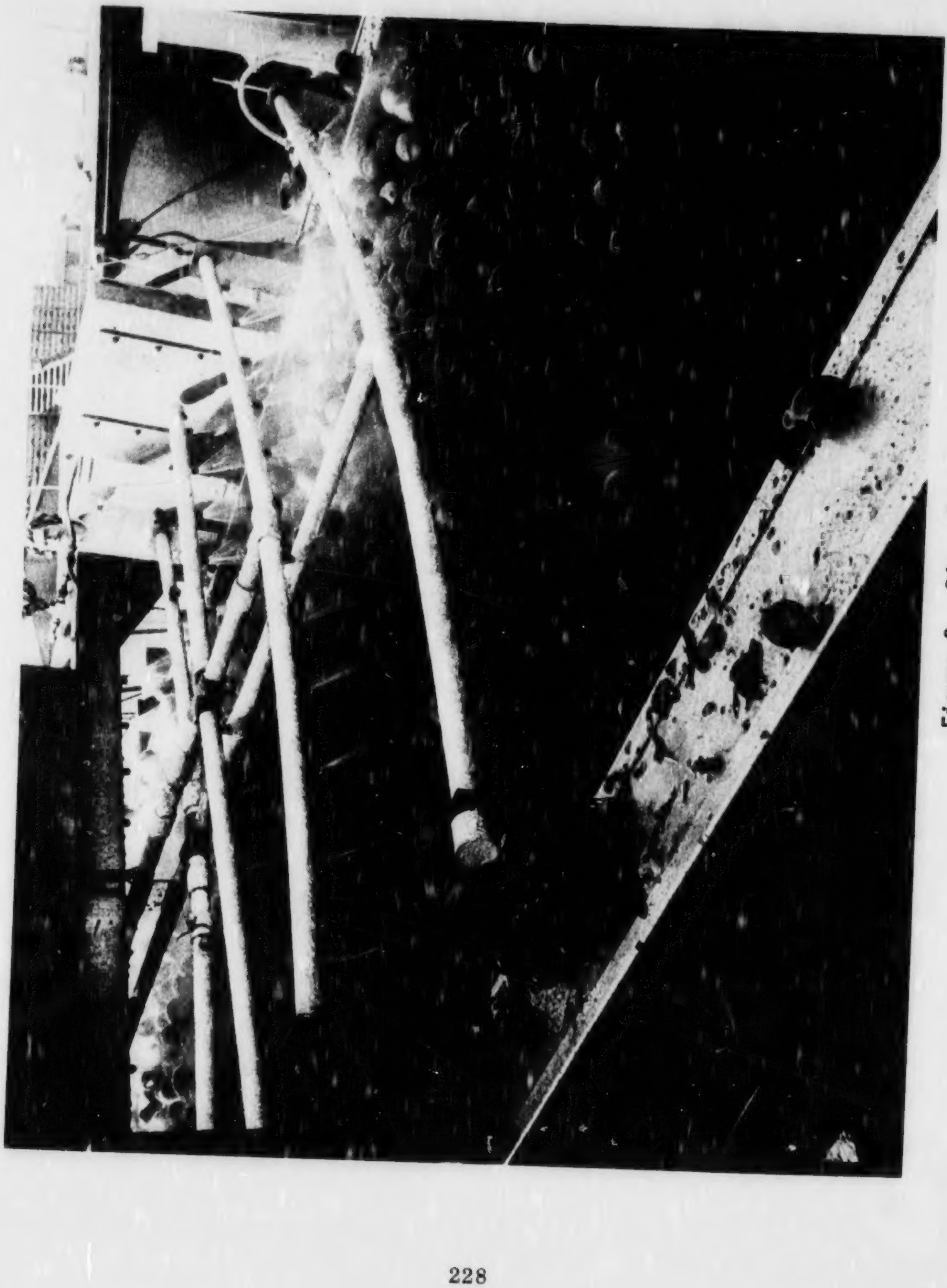

Figure 2. Disc cleaner.

Table 1. SUMMARY OF INITIAL TEST RESULTS

Cleaning system	Fixed suspended solids		Mesophilic aerobic spores	
Conventional washing system				
Location	ppm	% red	per ml	% red
Bin	86	-	2,461	-
Dump tank	59	31	562	77
Inside wash	38	56	147	94
Final rinse	6	93	50	98
Disc cleaner with hollow cone nozzle				
Location	ppm	% red	per ml	% red
Bin	82	-	1,067	-
Dump tank	50	39	731	31
Disc cleaner	27	67	198	81
Disc cleaner with combination of nozzles				
Location	ppm	% red	per ml	% red
Bin	116	-	3,230	-
Dump tank	81	30	1,178	64
Disc cleaner	14	88	140	96

water to process the tomatoes is greater. Should the disc cleaner results be compared to those from the inside washer, then tomatoes from either system are equally clean.

Results of this test program were discussed with cannery personnel and with the visual observations of the tomatoes during the test phase, concurrence was given to initiate the evaluation. For the remainder of the season, either the conventional or the demonstration system was operated on a continuous 24-hour basis. The normal procedure was to operate the disc cleaner for 4 days, followed by 2 days of conventional processing. Tables will be given to illustrate seasonal averages for various conditions of operation.

Table 2 gives results for tomato samples collected from various sample locations. Results are given for total plate count (TPC) and mesophilic aerobic spores (MAS). Results are tabulated for the conventional washing system and for the disc cleaner operated with the two types of spraying arrangements.

The results given in Table 2 follows a similar pattern obtained from the initial test phase. For the disc cleaner results are better when operated with a combination of sprays rather than the hollow cone nozzles. The best results were obtained from tomatoes sampled after the final rinse. The spread in percent reduction of spores for the two types of sprays on the cleaner is not as great on a season average as compared to the initial test results. The percent spread for the initial results between hollow cone and combination of sprays was 81 percent versus 96 percent; seasonal summary results were 77 percent versus 81 percent. The disc cleaner results, compared to those from the washer of the conventional system are much better than those indicated by the preliminary test program. This may be the result of sampling over a longer period of time and reflect the tendency for bacteria to grow in water which has been recirculated for extensive periods of time.

Table 3 is a summary of suspended and fixed suspended solids for tomatoes sampled under three cleaning modes. The general pattern for these results is similar to those presented in Table 2 for total plate count and mesophilic aerobic spores. Of the two solids parameters, fixed suspended solids more closely fits the pattern for the bacteria data. This would suggest that fixed suspended solids might serve as a quick indicator of microbial quality, especially mesophilic aerobic spores. Spores and fixed suspended solids are normally associated with soil load.

Total suspended solids, as mentioned above, fits the general reduction pattern obtained from Table 2. However, suspended solids is highly influenced by the quality of the incoming fruit (soft versus hard

Table 2. CLEANING OF TOMATOES - SUMMARY OF TOTAL PLATE COUNT ($x10^{-4}$) AND MESOPHILIC AEROBIC SPORES, PER GRAM OF TOMATOES

Cleaning system	TPC		MAS	
Conventional washing system				
Location	Avg.	% red.	Avg.	% red.
Bin	1,841	-	1,043	-
Dump tank	1,167	37	971	7
Washer	702	62	612	42
Final rinse	141	92	86	92
Disc cleaner with hollow cone nozzle				
Location	Avg.	% red.	Avg.	% red.
Bin	1,743	-	1,862	-
Dump tank	827	53	1,532	18
Disc cleaner	243	86	432	77
Disc cleaner with hollow cone and flat jet nozzle				
Location	Avg.	% red.	Avg.	% red.
Bin	1,456	-	1,946	-
Dump tank	1,414	3	1,040	46
Disc cleaner	228	84	379	81

Table 3. CLEANING OF TOMATOES - SUMMARY OF TOTAL AND FIXED SUSPENDED SOLIDS, PARTS PER MILLION

Cleaning system	TSS		FSS	
Conventional washing system				
Location	Avg.	% red.	Avg.	% red.
Bin	189	-	111	-
Dump tank	179	5	86	22
Washer	99	48	30	73
Final rinse	46	76	8	93
Disc cleaner with hollow cone nozzle				
Location	Avg.	% red.	Avg.	% red.
Bin	213	-	119	-
Dump tank	153	28	69	42
Disc cleaner	114	46	30	75
Disc cleaner with hollow cone and flat jet nozzle				
Location	Avg.	% red.	Avg.	% red.
Bin	205	-	129	-
Dump tank	109	47	48	63
Disc cleaner	84	59	18	86

or overripe versus underripe) and as such should more closely correlate with the BOD or COD content on the processing waters rather than the sanitary quality. No attempt has been made to look at the raw data to determine if this is in fact true.

Table 4 is a summary of water used and waste generated. Results are expressed as gallons per ton of tomatoes processed or pounds of COD per ton of tomatoes processed.

Certain estimations and assumptions were made in order to develop some of the data in Table 4. The volume of water used in the final rinse was metered; therefore, the 130 gallons per ton is an accurate figure. To calculate the pounds of COD per ton, it was assumed that the 130 gallons per ton of rinse water did co-mingle with the distribution flume circulation loop and that a sample of the excess water was an indication of the waste generation for the final rinse-distribution flume.

Some 1,981 gallons per hour of water was used inside the plant. Some of this water was used to fill the flood washer and some was used for clean-up purposes. Since the volume of water for each is not known, it is assumed that 25 percent of the water was for the flood washer and 75 percent was used for hosing down. To calculate the pounds of COD, it was assumed that the 130 gallons per tons of excess water from the distribution-final rinse and 25 percent of the 1,981 gallons per hour (16 gallons per ton) overflowed from the flood washer recirculation system.

The dump tank overflow was derived by assuming total excess flow from the inside washer plus bin washing water. The excess overflow was assumed to be 146 gallons per tons and the bin rinse water to be 20 gallons per ton. The inside gutter, a measure of all water used in the washing and transporting of tomatoes, is the sum total of the excess water from the bin dumping and that water used for cleaning.

Table 4 also gives the water and waste generation for the disc cleaner when operated under the two types of spray arranagement. Water usage by either mode is significantly lower than the other operations and supports the concept of using mechanical energy as a major substitute for hydraulic energy.

DISCUSSION

As discussed in Part II on the development of a water recycle system, a high velocity of water in the dump tank was required to

Table 4. WATER AND WASTE GENERATION - SUMMARY

System	Gallons/ton	Pounds COD/ton
Final rinse - distribution flume	130	1.0
Inside washer	146	2.44
Dump tank	166	2.02
Inside gutter	216	2.23
Disc cleaner - hollow cone nozzle	3.3	0.1
Disc cleaner - combination nozzles	24.7	0.42

prevent soil deposition. This considerably shortened the contact time between water and tomatoes and may have resulted in insufficient wetting time. The result of this short exposure time would be tomatoes delivered to the disc cleaner that still contained dried surface soil. Since the residence time of tomatoes on the disc is short (less than 30 seconds) it is important that smear soil be thouroughly wetted before being removed.

To increase the product-water contact time, it has been suggested that the dump tank be reconstructed with a false bottom. The water velocity above the dump tank bottom could be decreased. Below the false bottom, a high water velocity could be maintained to scour and transport the soil towards the water recycle pump intake.

During the course of the study, it was observed on several occasions that clods of dirt were being collected in the distrubition flume following the disc cleaner. This is another indication that there was insufficient residence time in the dump tank. The advantages from increasing this residence time would be the possible improvement to tomatoes being cleaned by the discs and maintenance of a higher quality distribution flume water.

Near the end of the season, it was noted that some of the cleaner discs were separating at the fillet juncture. This situation became progressively worse with time and, at the conclusion of the test program, it was estimated that over 25 percent of the discs had separated at the fillet. This matter was brought to the attention of several concerned parties, with agreement that the problem was caused by having too sharp of an angle between the thick and thin part of the disc. It has been recommended that new discs be manufactured which have a greater taper at the fillet juncture.

Some other minor modifications should be made on the disc cleaner as a result of observations made during the study period. The two side walls need to be increased by approximately 4 inches to prevent occassional tomatoes from bounding off the disc bed and onto the floor. Permanent spray headers should be installed and their height above the disc bin should be increased to improve clean up and appearance. There is a need to improve the drive mechanism. The two main drive chains were stretched and had to be tightened several times. The two small chains at the front of the cleaner also stretched and had to be tightened. These matters have been brought to the attention of the manufacturer and solutions have been suggested that should be incorporated into the cleaner before it is operated another season.

As operated in 1974, it is difficult to assess the water savings and/or the benefits to be derived from the operation of the disc cleaner. With the present set-up, tomatoes are flumed to the final inspection belts and given a final rinse. This rinse water is added back to the distribution flume as make up water. After several uses this water is eventually discharged from the dump tank.

When the disc cleaner is used, there is no need for the inside washer. As previously indicated, some 1,981 gallons of water per hour is used for either filling the washer or hosing down the inside area. Therefore, a potential water savings, from the use of the disc cleaner, could be the total elimination of that water or 33 gallons per ton. If the disc cleaner is operated with hollow cone nozzles (3.3 gallons per ton), the water reduction would be approximately 30 gallons per ton or 20 percent reduction in total water usage.

Another benefit from the use of the disc cleaner, and this aspect has not been fully evaluated, is the potential for a higher quality of water in the distribution flume recirculation system. Limited data on this water system, compared when the two types of cleaning systems are used, indicated the water to be cleaner when the disc cleaner is used. For example, fixed suspended solids is lower (180 versus 229) as is suspended solids (391 versus 431) and COD (847 versus 1,126). If the combination of sprays is used, rather than the hollow cone nozzles, then the comparison is even better, for fixed suspended solids (180 versus 229), suspended solids (256 versus 431) and COD (800 versus 1,126). However, water is increased from 3.3 gallons per ton to 24.7 gallons per ton.

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TOMATO CLEANING AND WATER RECYCLE

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George E. Wilson

Part II: Dump Tank Water Recycle System

INTRODUCTION

On March 15, 1974, the National Canners Association Research Foundation, Berkeley, California, submitted a proposal entitled, "Tomato Cleaning and Water Recycle", to the Grants Administration Division of the US Environmental Protection Agency. Subsequent to this submitted document, it was decided that EUTEK Process Development and Engineering would be responsible for the design, construction, and operation of the water recycle system. The design work officially began with project authorization in mid-June. Fabrication of the settleable solids removal unit processes was completed by the end of August. Testing of the settleable solids removal system was initiated during the first half of the month of September. The flocculation system was completed and tests were initiated by September 20. The tomato processing season was terminated during the first week of October.

The objective of the test program was to determine if it would be feasible to maintain a closed loop system of water usage around the tomato bin dump. Under normal operating circumstances, substantial quantities of overflow waters are discharged from the bin dump in order to maintain control of accumulations of settleable solids within the bin dump and suspended solids in the bin dump waters.

Another major objective of the water recycle system was to prevent accumulation of settleable solids within the bin dump and to remove these settleable solids in an elevated thickener which would allow their disposal as a solid waste. The third major objective of the test program was to determine what benefit was to be gained through employing a flocculation system for suspended solids removal in conjunction with the settleable solids removal system.

EXPERIMENTAL PLAN

System Design

Figure 1 is the flow diagram of the water recycle system as proposed for the 30 tons per hour tomato bin dump. The system operates either with or without flocculation. Operating without flocculation, the primary pump transfers water from the base of the elevator to the swirl concentrator. Concentrated settleable solids continuously discharge from the swirl concentrator to the thickener located below. This underflow is orifice-restricted to a constant flow of 50 gallons per minute. The balance of the recycled water overflows from the swirl concentrator and discharges through return scouring jets located in the base of the bin dump. The clarified underflow stream overflows from the thickener and returns to the bin dump.

An additional scouring jet header operates directly off the primary pump discharge line. This additional flow is required to obtain design flows through the scouring jets.

Supply water for the flocculation system was taken from the swirl concentrator overflow water returning to the scouring jets. Coagulant added to this flow and mixed through a mixing section resulted in a flocculated admixture from the Flocculator/Concentrator. The clear water overflow returns directly to the bin dump while the underflow returns to the thickener for gravity clarification.

System Construction

All elements of the system were fabricated with the exception of the primary and secondary supply pumps, valves, and piping. Figure 2 shows a view of the elevated swirl concentrator thickener assembly following construction.

System Operation

The experimental plan called for operation of the water recycle system in an operating mode for settleable solids removal and an

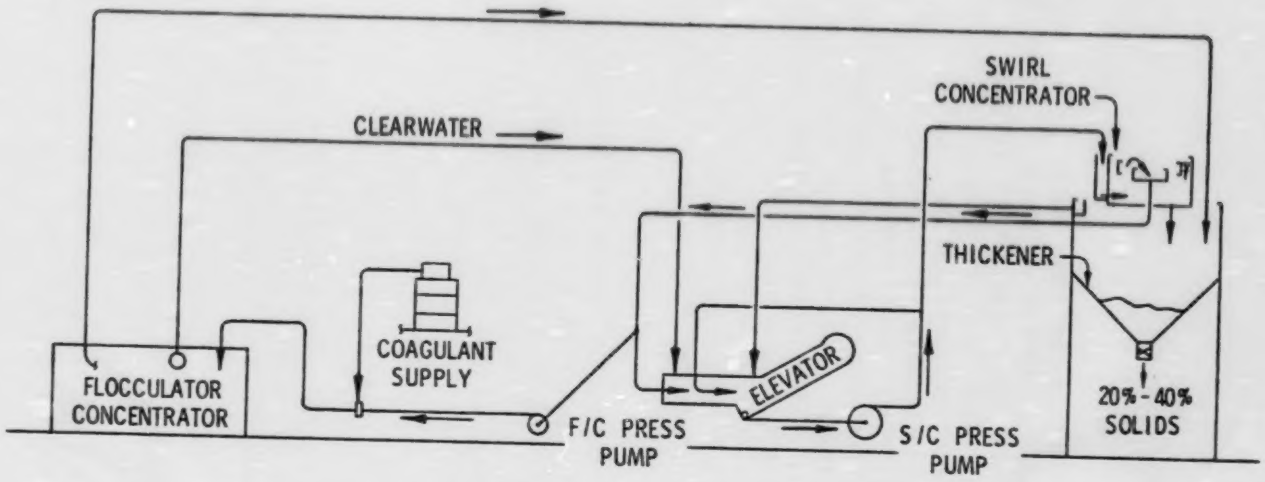
SWIRL CONCENTRATOR
CLEARWATER
THICKENER
COAGULANT SUPPLY
ELEVATOR
FLOCCULATOR CONCENTRATOR
F/C PRESS PUMP
S/C PRESS PUMP
20% - 40% SOLIDS

Figure 1. Flow diagram of water recycle system.

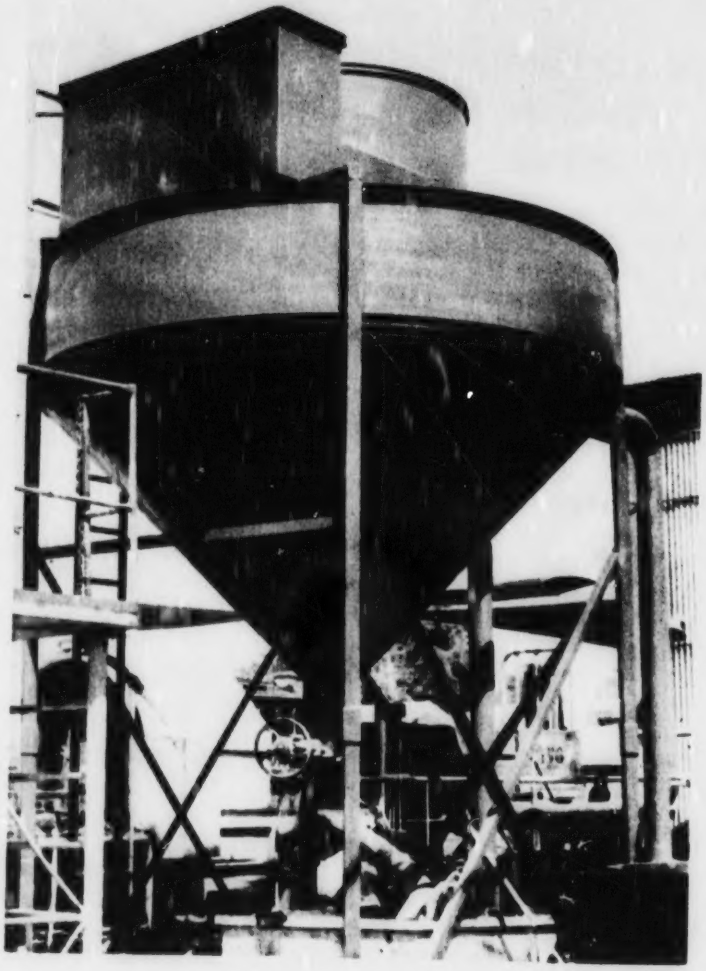

Figure 2. Swirl Concentrator/Thickener.

operating mode for both settleable solids and suspended solids removal. The former mode utilizes only the swirl concentrator and thickener and the latter mode also employs the Flocculator/Concentrator. Following completion of tests in both operating modes, the data was analyzed and subsequent tests were conducted to better determine system operating characteristics.

EXPERIMENTAL RESULTS

Hydraulic and Mass Balances

Problems were encountered due to accumulation of grass and vines in the water recycle system. Water flow rates varied significantly from one test day to the next. On some operating days, meters monitoring accumulated water flows were found plugged and inoperative, throwing into doubt the value of data collected during that time. The grab sampling technique employed to determine the swirl concentrator removal efficiencies did not account for the rapid and significant changes in settleable solids concentrations due to the irregular nature of the bin dump operation. Due to the difficulty of keeping accurate records of the actual operating periods of the water recycle system, the record sheets had several gaps in them.

To arrive at an estimate of the system performance selected operating days were taken which had reasonably long operating periods as evidenced by the amount of sludge removed from the thickener. Accumulated sludge removal records were extrapolated to arrive at estimates of operating periods in order to make hydraulic and mass balances.

Figure 3 defines and summarizes the abbreviated notation and format for the hydraulic and mass balances.

Table 1 summarizes the hydraulic and mass balance relationships employed to arrive at estimates of the system flows, loadings and efficiencies. Metered and calibrated flows in the system were used as shown on Table 1 to compute the unknown flows. Mass balances were obtained as shown. The quantity on the left hand side of the equation was determined as a function of the quantities on the right hand side.

Table 2 summarizes the flows and loadings for the selected operating days for performance comparisons of the system with and without flocculation. As previously mentioned, the record of solids removal from the thickener was used to determine the effective operating

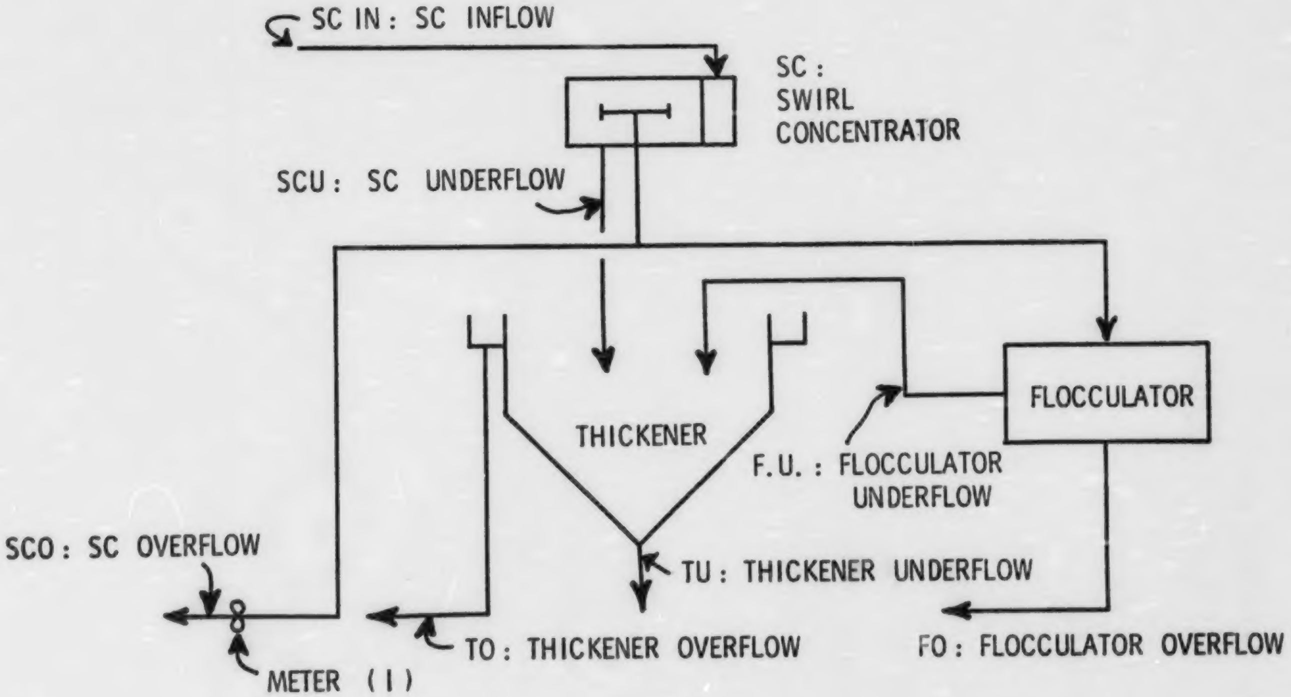
SC IN : SC INFLOW
SC :
SWIRL
CONCENTRATOR
SCU : SC UNDERFLOW
THICKENER
FLOCCULATOR
F.U. : FLOCCULATOR
UNDERFLOW
SCO : SC OVERFLOW
TU : THICKENER UNDERFLOW
TO : THICKENER OVERFLOW
FO : FLOCCULATOR OVERFLOW
METER (I)

Figure 3. Flow diagram for hydraulic and mass balances.

Table 1. HYDRAULIC AND MASS BALANCE RELATIONSHIPS

1. Hydraulic balances, mgd
   a. $Q_{SCIN} = Q_{SCO} + Q_{FO}{}^{a} + Q_{FU}{}^{b} + Q_{SCU}{}^{c}$
   b. $Q_{TO} = Q_{SCU} + Q_{FU} - Q_{TU}$
2. Mass balances, lbs
   a. SCU = TU + TO - FU
   b. SCIN = SCO + FO + SCU
3. Efficiencies
   a. Thickener removal, %: 100 TU/(SCU + FU)
   b. Overall removal, %: 100 TU/SCIN
4. Concentration factor
   a. Swirl concentrator factor: (Q_{SCIN}/Q_{SCU}) (SCU/SCIN)

[a] Constant flow of 0.043 mgd when floc. system operating.
[b] Constant flow of 0.058 mgd when floc. system operating.
[c] Constant flow of 0.072 mdg at all times.

Table 2. SUMMARY OF FLOWS AND LOADINGS[a]

Date	Operating period, days	SCIN		SCO		FO		FU		TO		TU	
		mgd	lb	mgd	lb	mgd	lb	mgd	lb	mgd	lb	mgd	lb
Without flocculation													
13 Sep	0.83	0.230	2,436	0.158	3,062	-	-	-	-	0.070	210	0.015	899
17 Sep	0.71	0.438	2,228	0.366	2,264	-	-	-	-	0.070	204	0.010	1,209
With flocculation													
20 Sep	0.67	0.337	5,122	0.164	1,393	0.043	365	0.058	493	0.127	44	0.015	6,262
27 Sep	0.28	0.286	1,429	0.217	1,622	0.043	222	0.058	430	0.127	123	0.006	2,286

[a] Lb TSS except TU which is lb TS.

period for the system on each selected day. This assumption was based on the constant flow to the thickener and the assumption that the measured composite solids concentration was the average concentration of all sludge volumes. Figure 4 is a plot of cumulative thickener underflow volumes versus the time of day at which these volumes were removed. The envelope line over the data points was assumed to represent the average solids accumulation within the thickener. Extrapolation to zero volume determined the operating period for the day. Comparison of the values obtained in this manner with available records indicated that the procedure was reasonably accurate in predicting operating periods. Table 2 operating periods were obtained in this manner.

Flows and loadings on Table 2 were obtained by utilizing the hydraulic and mass balance relationships shown on Table 1 together with the measured solids concentrations of the respective process streams.

Coagulant Requirements

When the flocculation system was in operation, a simulated bench scale system was employed to determine the optimum coagulant concentration. The resulting coagulant dosage was then compared with that obtained employing the traditional jar test procedure to determine what differences, if any, existed between the two techniques.

Figures 5 through 7 illustrate the principle features of the bench scale apparatus, or "calibrator". Figure 5 illustrates the portion of the calibrator simulating the Flocculator/Concentrators. It will be noted that the process stream in this portion of the system has a definite separation of solids in the lower portion of the coil flow. This separated two-phase flow was then introduced into a flow dividing tee as shown on Figure 6 in which the high solids concentration portion was separated from the clear water. The high solids concentration stream was then introduced into a bench scale solids thickener (Figure 7). Performance of the bench scale apparatus was observed and adjusted to an efficient operating point. This dosage was then utilized in the full scale flocculation system.

Figure 8 illustrates the results of jar tests run during the September 20 day of operation. The coagulant dosage for the water recycle system was significantly less than that for the conventional bin dump system when water recycle was not being practiced. This was apparently due to the presence of a singificant settleable solids fraction in the bin dump waters under these circumstances. As indicated, with the water recycle system operating, the optimum

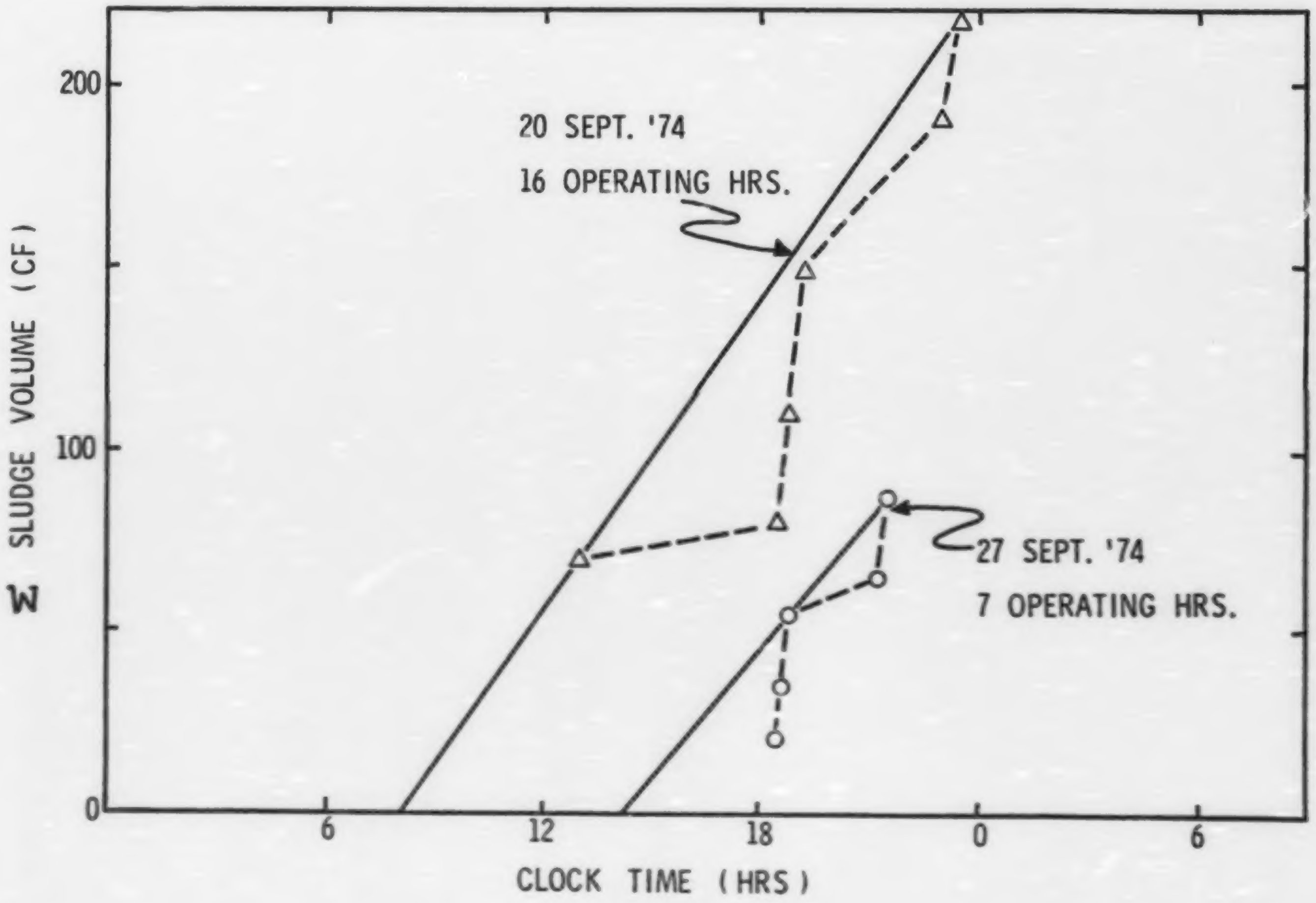

Figure 4. Cummulative thickener underflow volumes.

Figure 5. Bench scale Flocculator/Concentrator.

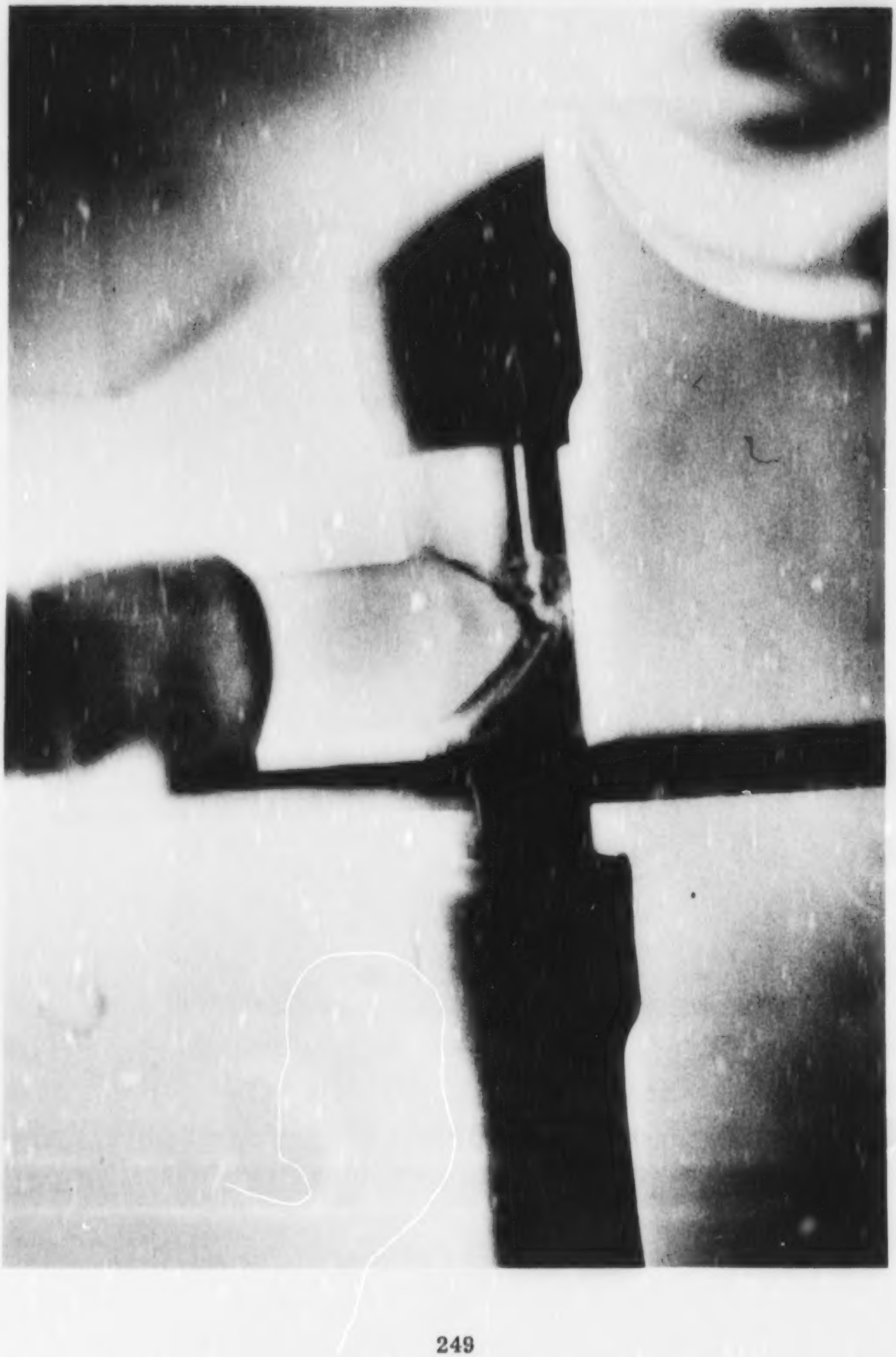

Figure 6. Flow splitting tee.

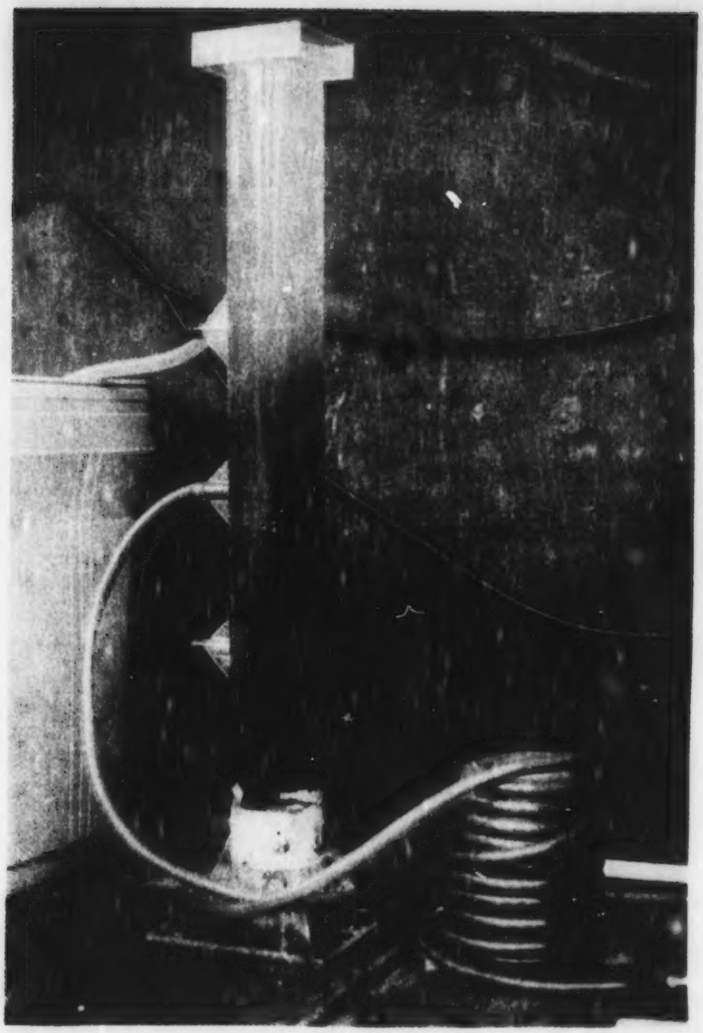

Figure 7. Bench scale thickener.

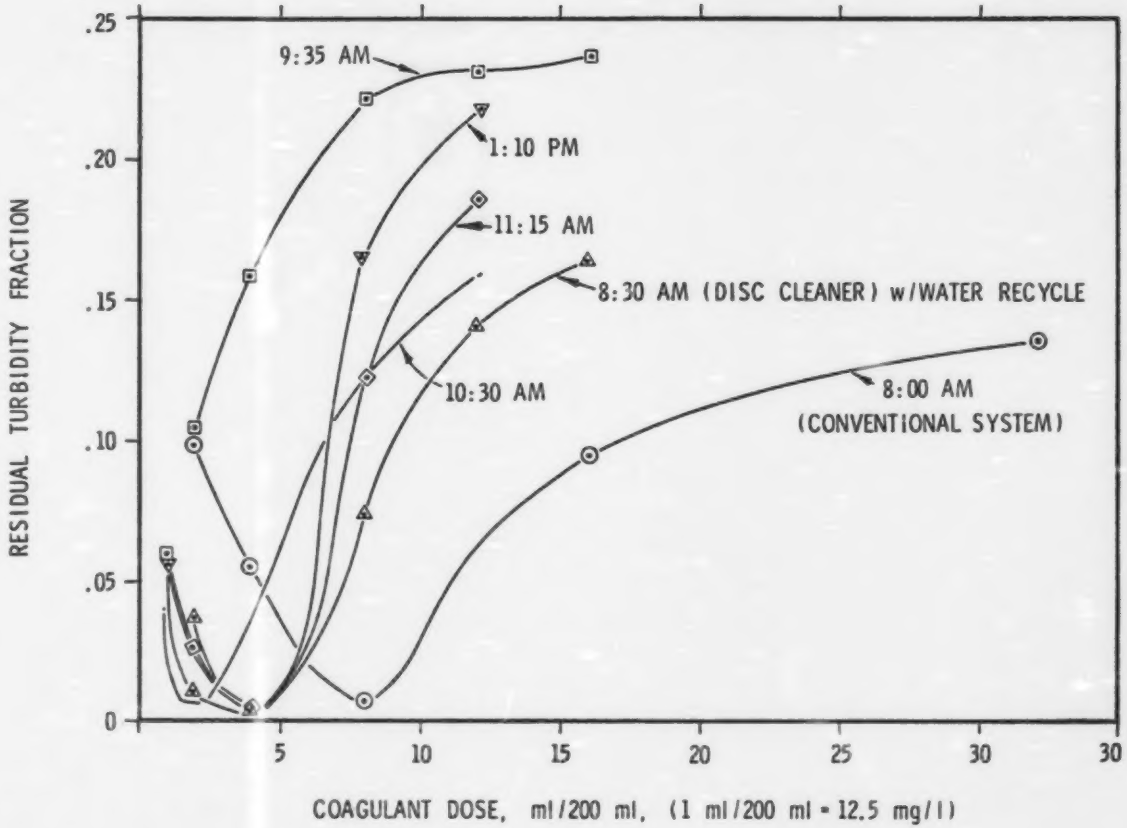

Figure 8. Jar test results - September 20, 1974.

coagulant dosage varied from 20 to 50 milligrams per liter. Similar concentrations were found optimal for the bench scale calibrator.

DISCUSSION

Experimental Results

Table 3 summarizes the results of the hydraulic and mass balances discussed. The first two days of operation which were investigated were the 13th and 17th of September. On the 13th of September as indicated on Table 3, the swirl solids concentrator factor was approximately unity, indicating relatively little settleable solids in the bin dump waters. This fact was confirmed by grab samples taken on that day which indicated very little if any settling within a 30-second period. The thickener solids underflow concentration was correspondingly low. In spite of the suspended solids, the thickener removal efficiency was a reasonable 81 percent. Overall system solids removal was 22 percent for that day, indicating the approximate fraction of settleable solids in the bin dump waters. On the 17th of September, the bin dump waters contained appreciably more settleable solids as evidenced by the swirl solids concentrator factor. Thickener underflow solids concentration was correspondingly doubled. In spite of the increase in the fraction of settleable solids, there was relatively little change in the thickener solids removal efficiency and the overall system solids removal efficiency.

September 20 was the first full day of operation with the flocculation system. As indicated by the swirl solids concentrator factor, this day was also characterized by significant quantity of settleable solids in the bin dump waters. The thickener underflow solids concentration, however, increased disproportionately and can only be explained by the effect of the addition of the coagulated solids to the thickener. The residual solids in the thickener overflow were dramatically reduced on this day with overall system removal efficiencies significantly higher than any experienced up to that time.

The next reasonably long operating period of the flocculation system occurred on the 27th of September with a reasonably large swirl solids concentrator factor. In comparing the thickener underflow solids concentration of the 27th of September with the 17th of September, some appreciation can be gained for the effect of the addition of coagulated solids to the thickener in increasing the solids underflow concentration. The thickener solids removal efficiency was still significantly higher than that when the system was operated without

Table 3. PERFORMANCE SUMMARY

Date	Swirl solids concentrator factor	Thickener underflow solids, g/l	Thickener solids removal, %	Overall solids removal, %
Without flocculation				
13 Sep	1.0	60.0	81	22
17 Sep	2.3	120.9	86	33
With flocculation				
20 Sep	3.4	417.9	99	78
27 Sep	1.9	346.4	95	54

flocculation. The overall system solids removal efficiency was 54 percent.

Figure 9 is a plot of the thickener performance as measured by the underflow solids concentration and the solids removal efficiency as a function of the swirl solids concentrator factor. On the basis of the limited data analyzed, it appears that the thickener underflow solids concentration is increased by approximately 250 grams per liter when the flocculation system was employed. Residual solids in the thickener overflow are reduced 3 to 4 times with the flocculation system operating. For effective solids removal and efficient water reclamation, the water recycle system must be operated with the flocculation system and flows of uncoagulated material to the thickener should be excluded.

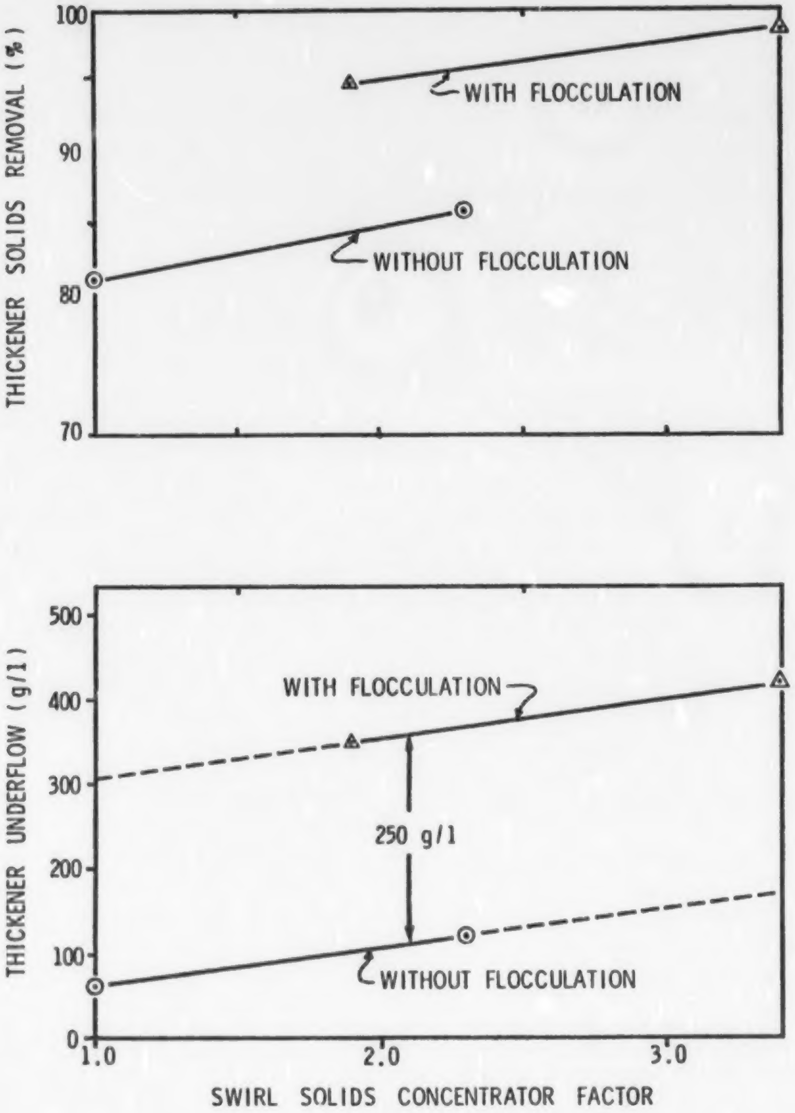

Figure 9. Thickener performance correlation.

MEATPACKING WASTEWATER TREATMENT BY SPRAY RUNOFF IRRIGATION

Jack L. Witherow*
Mickey L. Rowe**
Jimmie L. Kingery***

INTRODUCTION

Spray runoff irrigation is a treatment process in which wastewater is applied to sloping, plant covered land. The process yields a treated effluent which is collected on the toe of the slope for discharge. The process is also referred to as an overland flow system or a living filter. Utilization of the system is dependent upon such variables as available land, soil type, topography, climate, location, and wastewater characteristics. Vegetable processing plants using this process require a land area of about 100 acres per million gallons per day.[1] Clay type soils are needed to control infiltration and to promote runoff. Also necessary is a surface with a 2 to 6 percent slope which is smooth enough to prevent pooling or channelization of flow.

While spray runoff irrigation has many advantages, there are inherent problems to be overcome. Solids and grease in the wastewater may build up deposits under the spray pattern and result in anaerobic conditions. The potential for odors, insects, and aerosol drift restricts locating this treatment process near residential areas. Precipitation and freezing temperatures limit wastewater application; however, this can be overcome through use of storage facilities.

This report presents a study on a pilot scale spray runoff irrigation system. The objectives of the study were: (1) to determine

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if the system would sufficiently treat meatpacking wastewaters to meet national discharge limitations, (2) to ascertain whether a goal of 80 percent removal of both total nitrogen and phosphorus could be achieved to meet future environmental needs, and (3) to establish the economic feasibility of the system.

EXPERIMENTAL DESIGN

A previous study[2] had shown that a meatpacking waste which had received treatment in an anaerobic lagoon could be treated by spray runoff irrigation to meet average discharge limits for 1977. (At the time of the study maximum daily limits had not been proposed.) However, use of an anaerobic lagoon prior to spray irrigation can create a nuisance. Protein and sulfates in the wastewater will be reduced in the lagoon to ammonia and hydrogen sulfide, respectively. These will be released to the atmosphere by the spraying action. This potential problem may be eliminated and the system design may be simplified by using raw meatpacking wastewater in the irrigation process.

Spray runoff irrigation of meatpacking wastewater was studied for six months in a pilot plant at the W. E. Reeves Packinghouse in Ada, Oklahoma (Figure 1). Application of the waste began in January and ended in June, allowing evaluation under both cold and warm weather conditions. The raw wastewater was diverted from a manhole several minutes each hour to obtain the limited quantity needed and to composite a wastewater representative of the plants daily flow. The wastewater passed through a hydrosieve with a 0.020-inch slot openings and was stored in a 2,100 gallon tank (Figure 2). The hydrosieve was used for removal of solids which would clog the spray nozzles. The storage tank was used to equalize flow and to give a positive pressure on the pump inlet. The storage tank was aerated to prevent anaerobic conditions and solid-liquid separation.

Each of the three 0.1 acre irrigation plots were 33 feet by 115 feet. The site for the plots had 3 to 12 inches of soil over conglomerate rock. A clay loam soil was added to form a smooth surface with a 6 percent slope. The increased soil depth ranged from 1 to 4 feet. A native bermuda grass was grown on the plots to provide a deep mat for bacterial growth and erosion control. A berm was placed on the upper end of the plots to divert rainfall runoff. Aluminum stripping was placed around each plot to direct the spray runoff through an outlet structure where flow was measured by a tripping bucket and counter arrangement.

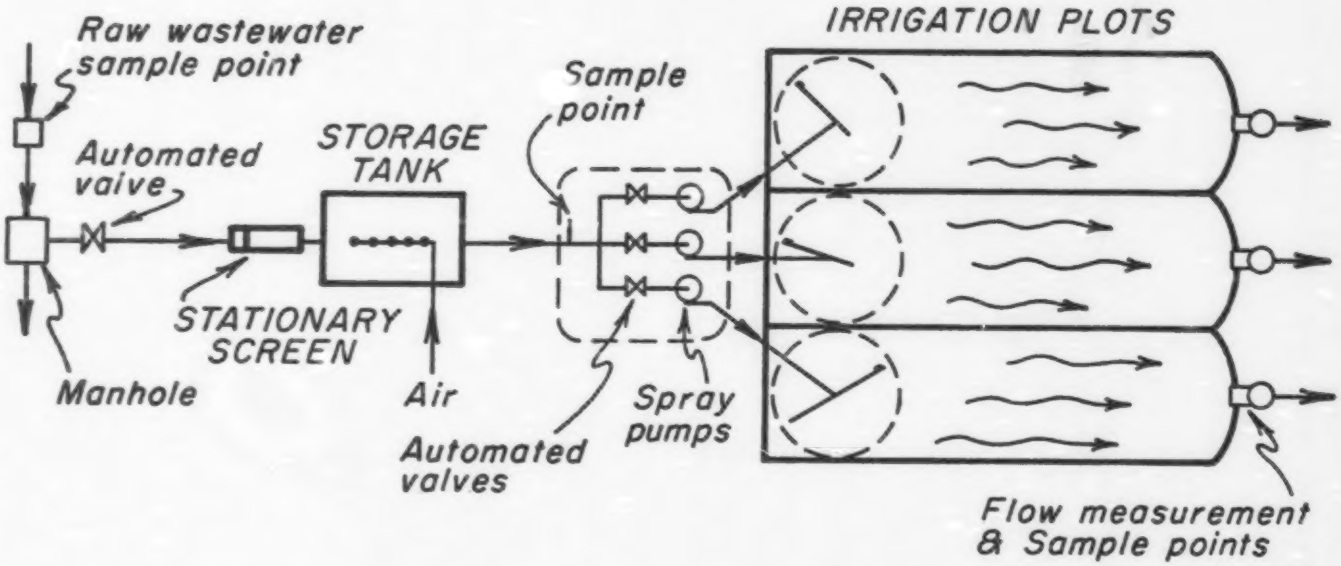
Raw wastewater sample point
Automated vaive
STORAGE TANK
Sample point
IRRIGATION PLOTS
Manhole
STATIONARY SCREEN
Air
Automated valves
Spray pumps
Flow measurement & Sample points

Figure 1. Spray runoff irrigation pilot plant.

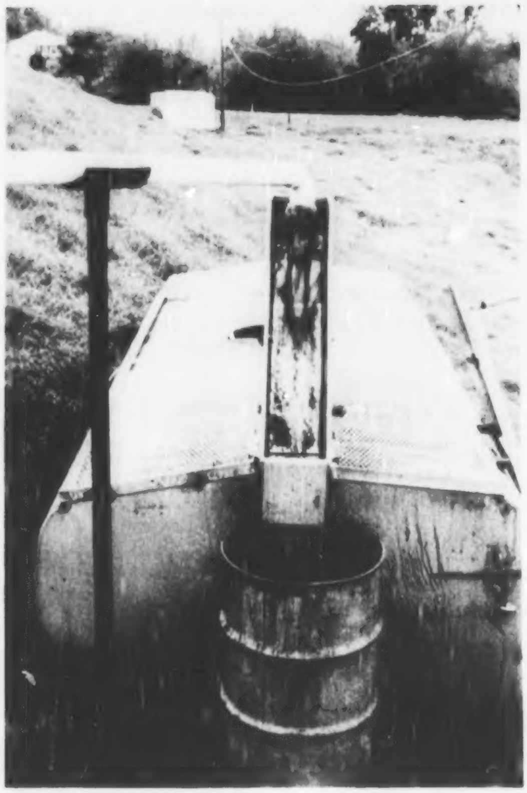

Figure 2. Hydrosieve and aerated storage tank.

Because revolving irrigation guns were not successful on these small plots, revolving booms with nozzles at the ends were used to provide even distribution of flow across the plot (Figure 3). The radius of the spray pattern was adjusted to remain within the 33 foot width. Health hazards from aerosol drift due to high pressure application had caused Tarquin et al.[3] to also use low pressure booms. Constant speed positive displacement pumps were used to apply and measure the flow to the three soil plots. These pumps were operated up to 55 hours per week during the regular hours of plant operation. The flow per minute for each plot was measured by catching the nozzle discharge, and application rates were established by controlling the time each pump was operated per day.

Weekly samples were taken of the raw wastewater, of the screened and aerated wastewater applied to the soil plots and of the effluent from each plot. Automatic composite samples were taken of the raw wastewater and wastewater applied to the plots. Grab samples were taken of the three plot effluents. Previous experience with this process had shown that grab samples of these effluents were satisfactory.[4] The automatic samplers were activated to take four samples per hour during the slaughtering and/or processing operations in the packinghouse. Samples were time composited in iced containers. Collected samples were stored at 4 degrees C in the laboratory.

The weekly samples were analyzed for five-day biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), pH, total solids (TS), total volatile solids (TVS), total suspended solids (TSS), ammonia (NH_3-N), nitrite plus nitrate (NO_2+NO_3-N), total Kjeldahl nitrogen (TKN) and total phosphate (T-P). In situ measurements were made for temperature and dissolved oxygen (DO) during sample collection. Once a month specially collected samples were analyzed for oil and grease (FOG), settleable solids and fecal coliforms.

All analyses were made in accord with EPA Methods for Chemical Analysis of Water and Wastes, 1971. The chemical analyses were subjected to quality control procedures. Duplicate analyses were run on 10 percent or more of the samples. The sum of the squared differences was plotted on a quality control chart for each analysis. When the difference was outside of the established boundaries, the samples were analyzed again. Standards were also run on most analyses. In the middle of the study period, two sets of unknown reference samples were analyzed for BOD_5, COD, NH_3-N, TKN and T-P. All results were within one standard deviation of the true value.

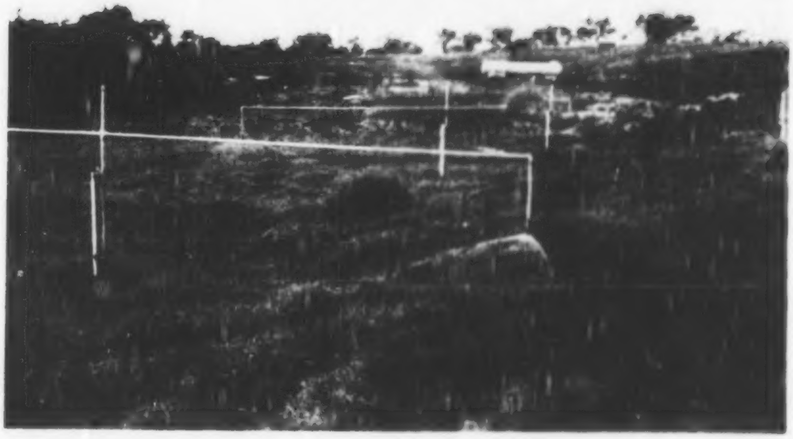

Figure 3. Distribution system and irrigation plots.

Sampling Accuracy

Solids-laden waste streams are difficult to sample. For this reason, an automatic sampler which dipped a container below the surface was selected for sampling the raw wastewater. It was hoped this sampler would eliminate the plugging and straining problems caused by small pumps and small diameter lines used in most samplers. The sampling location was designed to create turbulance for solids mixing and elimination of solids deposits. Harris and Keffer[5] have compared types of automatic samples and found vacuum samplers with high intake velocities obtain higher concentrations of parameters influenced by solids. On two occasions, dual samples were taken---one by the automatic dip sampler; the other by an automatic vacuum actuated sampler. All samples were time composited. The routine analysis on both samples showed the vacuum samples to be about 20 percent higher for BOD_5, COD, TS, TVS, TSS and about 20 percent lower for TKN than the dip samples. The automatic dip sampler apparently missed 20 percent of the solids in the waste stream.

An automatic sampler containing a centrifugal pump was used for sampling the screened and stored wastewater. The sampler was installed on the intake line to the spray pumps. To obtain representative solids levels, samples were only collected when the spray pumps were operating. To obtain a sample for comparison, an open container was placed under the spray pattern on one of the plots. Both samples were time composited. A comparison of the analyses revealed the pumped sample to be about 25 percent lower in COD, TS, TVS, and TSS, but about 75 percent higher in NH_3-N than the waste collected as it fell to the soil plot. Apparently the automatic sampler did not obtain all solids that had passed through the 0.02-inch screen openings and the spraying action scrubbed a significant amount of ammonia from the wastewater.

EXPERIMENTAL RESULTS

Screening and Storage

The passing of the raw wastewater through a 0.020-inch slot opening in a tangential screen and the aerated storage in a 2,100 gallon tank resulted in significant reduction in the waste strength. The concentrations and removals shown in Table 1 are based on mean values. The concentrations of BOD_5, COD and TSS may be 20 to 25 percent low because of automated raw waste sampling. Additional statistical data on the influent and effluent are in the Appendix.

Table 1. EFFECTS OF SCREENING AND STORAGE

Items	Influent, mg/l	Effluent, mg/l	Removal, %
BOD_5	634	374	41
COD	1,675	936	44
TSS	499	219	57
FOG	139	67	52

The screen served the intended purpose of removing the large soilds and preventing plugging of the spray nozzles. Screens offer the advantage of removing solids (bone, hair, toenails and plastics) that would not be treated by the irrigation process. The pilot scale operation made the disposal of the screen solids a minor task. In a large operation, mechanized solids handling equipment would be needed.

Part of the raw waste flow was diverted from the packinghouse sewer a few minutes each hour by means of an automated valve. With this intermittent diversion, the storage tank was necessary for continual application to the spray plots. Air was introduced through a header at the bottom of the tank to mix the contents and to maintain aerobic conditions. The dissolved oxygen in the tank liquid averaged 0.8 milligrams per liter. The liquid detention time in the tank was calculated as averaging less than six hours, but liquid remained in the tank overnight. The tank was drained and flushed weekly to remove minor sludge deposits. Reduction of protein in these deposits is suspected as the cause of the average increase of 18 milligrams per liter of NH_3-N. In a full-scale operation, increase in ammonia could be minimized by standard wet well designs.

Loading on the Plots

The flow applications were initially set to increase phosphorus removal. The concept was to increase the liquid detention by applying the flow intermittently. The pumps and nozzles would deliver 0.07 inches per hour, but the flows to Plots 5, 6 and 7 were only applied 40, 30 and 20 minutes per hour, respectively. After two months of operation, it was concluded that this on-off application was not successful in increasing phosphorus removal. The emphasis was shifted to minimizing NH_3-N and NO_2+NO_3-N in the discharge. Minimum concentrations of these parameters were being obtained on Plot 5. To bracket the loading on this plot the application on Plot 7 was increased to 50 minutes per hour in mid-March. In mid-May, a period of high evaporation eliminated the surface discharges from Plots 5 and 6. To gain additional information, the application to Plot 6 was increased by running the pump continually 10 hours per day. The average flows applied to Plots 5, 6 and 7 during the study are given in Table 2.

Since the wastewater was applied to the three plots, the organic and nutrient loadings are directly proportional to the hydraulic loadings. The loading of BOD_5, COD, TSS, NH_3-N, T-N and T-P in pounds per acre per day are shown in Table 3. The nitrogen loading is important because a few states put limitations on this nutrient to protect ground water supplies. The wastewater had a ratio of BOD_5:N:P

Table 2. LOADING ON IRRIGATION PLOTS
(mean values)

Items	Units	Plot 5	Plot 6a	Plot 6b	Plot 7a	Plot 7b
Flow	gal/ac/day	10,490	9,050	16,610	6,560	14,800
BOD_5	lb/ac/day	32.7	29.5	47.7	21.8	45.0
COD	lb/ac/day	79.3	73.2	97.1	52.8	106.2
TSS	lb/ac/day	17.8	14.3	30.5	8.7	28.0
NH_3-N	lb/ac/day	2.8	2.1	5.8	1.1	4.9
T-N	lb/ac/day	9.4	8.2	14.6	5.0	14.2
T-P	lb/ac/day	0.6	0.5	0.9	0.5	0.7
(Operation in weeks)		21	15	6	8	14

Table 3. DISCHARGE FROM IRRIGATION PLOTS

Items	Units	Plot 5	Plot 6a	Plot 6b	Plot 7a	Plot 7b
Flow	gal/ac/day	2,510.	3,190.	1,120.	1,150.	4,570.
BOD_5	lb/ac/day	0.41	0.38	0.06	0.06	0.75
COD	lb/ac/day	4.21	5.09	1.06	0.94	5.25
TSS	lb/ac/day	1.04	0.73	0.21	0.15	1.12
NH_3-N	lb/ac/day	0.04	0.02	0.00	0.00	0.04
T-N	lb/ac/day	0.35	0.53	0.03	0.15	0.14
T-P	lb/ac/day	0.17	0.23	0.07	0.06	0.21
Temp.	°C	17.2	15.4	27.4	13.8	22.9
BOD_5	mg/l	10.0	5.8	5.2	6.0	10.1
COD	mg/l	123.	107.	103.	103.	132.
TVS	mg/l	270.	233.	179.	271.	215.
TSS	mg/l	25.	23	17.	17.	26.
NH_3-N	mg/l	1.2	0.5	0.0	0.6	0.5
T-P	mg/l	6.7	5.9	6.9	6.5	6.4

of 100:30:2, which is satisfactory for biological treatment processes. Additional data on loadings and concentrations are in the Appendix.

Discharge from the Plots

Removal efficiencies based on both concentrations and pounds of pollutants were calculated from the data in Tables 2 and 3 and the Appendix. Removal efficiencies were 90 percent or greater for all plots; exceptions were pounds of phosphorus and milligrams per liter of COD, TVS, and T-P. The percentages are not presented because, with one exception, they did not show any meaningful differences among plots. The exception was the pounds of phosphorus removed. This difference was the result of increased water loss during warm weather. Removal of phosphorus on the basis of concentration was similar among plots and less than 10 percent. However, average flow losses across the plots varied from 65 to 97 percent of that applied.

The average conditions given in Table 3 show all the plots to discharge low concentrations of pollutants and show minor changes in concentration among plots. The variation in hydraulic and organic loading conditions tested had little effect on removals. Two factors which mask the differences that occurred were the effects of the weather and the averaging of extremes. The weather caused these extreme conditions and was the singularly most significant factor in affecting discharge loads under the test conditions.

The loadings and weather conditions of Plots 6b and 7a were the most widely different; yet the discharges were remarkably similar. There was no meaningful difference in removal efficiencies based on pound of pollutants and, except for TVS, the concentration of the two discharges appeared identical. A statistical test showed no significant difference between the TVS means. Thus, a loading of 16,600 gallons per acre per day in the summer and a loading of 6,500 gallons per acre per day in the winter resulted in the same average volume and mass of pollutants in the discharges. The data on Plot 6b was collected in January, February, and March, and the data on Plot 7a was collected in May and June. The respective pan evaporation for these two periods averaged 3.5 inches per month and 9.0 inches per month.

A comparison of effluents from Plot 6 for a period of six weeks in April and May at a hydraulic loading of 9,000 gallons per acre per day with the following six weeks in May and June at a hydraulic loading of 16,500 gallons per acre per day showed little or no difference in concentration of pollutants. Almost doubling the hydraulic loading did not result in a noticeable decrease in removal based on concentration during these two warm periods.

Waste load discharges can best be controlled by matching hydraulic loadings with weather conditions to limit discharge volumes.

Rainfall Effects

Rainfall on wastewater irrigation plots can significantly increase the waste loads discharged in the runoff. Rainfall increases the volume of runoff and may increase the concentration of some pollutants in the discharge. Law et al.[4] evaluated the effect of rainfall by continuous measurement of electrical conductivity. They found that rainfall of 0.1 inch or less did not contribute enough volume to alter the composition of the runoff contributed by the applied wastewater. Rainfall events of 0.1 to 2.0 inches had a marked effect by steadily decreasing the conductivity with increasing amounts of rainfall. Rainfall events greater than 2.0 inches caused little additional reduction in conductivity. This information does not include runoff flow measurements and waste loads cannot be calculated. The information does indicate that waste load discharged are increased by rainfall events greater than 2.0 inches.

During this investigation, routine sampling occurred on three days when rainfall was part of the grab sample of the effluent. The rainfall intensity at the time of sampling was not measured, but the rainfalls ranged from 0.7 to 1.5 inches per day. In two of these three events the runoff volume exceeded that of the applied wastewaters. In these two events the pounds of phosphorus discharged were greater than that applied and the suspended solids discharged exceeded the maximum day limit in the Best Available Treatment (BAT) standards. In one event the BOD_5 discharged also exceeded the BAT daily limit. To specifically measure the effects of rainfall, composite samples of the runoff from the plots were taken during five rainfall events, outside of the routine sampling schedule. These samples were analyzed for TS, TVS, TSS and T-P. Total solids concentrations in the discharge samples taken during rainfall were considerably less than during non-rainfall periods. This is in agreement with the conductivity data reported by Law.[4] The over 15,00 milligrams per liter difference in TSS between the wastewater and rainfall can account for these decreases by dilution. Total volatile solids and total phosphorus did not differ significantly in concentration; however, suspended solids were usually higher and in one case the concentration was 10 times that of the previous sample taken during dry weather. Flow recordings were not taken during these rainfall events and pounds of TSS discharged cannot be computed. During rainfall, the discharge flow is certain to increase over dry weather discharges. During periods when wastewater is applied, rainfalls of greater than 0.7 inches per day can increase waste concentrations as much as 10 times average discharge values and maximum daily limits in the BAT standards can be exceeded.

A discharge volume was measured and sampled during a rainstorm when wastewater was not being applied. A rainfall of 0.62 inches was measured at the local weather station. The runoff from the plot was 230 gallons per acre. The concentrations of TVS and TSS were 240 milligrams per liter and 11 milligrams per liter, respectively, which were similar to discharge concentrations the next day when wastewater was applied and there was no rainfall. The rainfall runoff from the plot had a TS of 634 milligrams per liter, about half that in the next days sample. Rainfall on the irrigation plots can also result in a waste load discharge between periods when wastewaters are applied.

Effects of Temperature

Water temperature was measured at each sample point at the time samples were collected and minimum and maximum daily air temperatures were obtained from the local weather station. The two sources of heat were the plant's hot water system and the ambient conditions. The ambient conditions, as defined by air temperatures, were dominant and from January into April usually reduced the wastewater temperature as it passed through the collection and treatment systems. In late April, May and June, ambient conditions usually maintained a stable wastewater temperature through these systems.

Because the effect of temperature on biological treatment is well established, the study period was selected to encompass both cold and warm weather conditions. A statistical analysis was made to determine the correlation between effluent temperatures and concentrations of BOD_5, COD, NH_3-N, NO_2+NO_3-N and T-P for Plots 5, 6a and 7b. The analyses were made on effluent concentration rather than on change in concentration or removal efficiencies. These latter items were mainly controlled by the influent concentration, and temperature and influent characteristics are not usually related. The analyses gave no significant correlations between the parameters and temperature except for NO_2+NO_3-N. On both Plots 5 and 6a, a correlation coefficient of -0.71 was obtained. The average temperatures and average NO_2+NO_3-N levels for the three plots shown the same negative correlation.

Averages	Plot 6a	Plot 5	Plot 7b
Temperature, degrees C	15.8	18.2	25.6
NO_2+NO_3-N, milligrams per liter	10.8	4.6	0.5

The correlation for Plot 7b was not statistically significant, but the low concentration of NO_2+NO_3-N was meaningful. On the three plots, the effluent concentrations of NH_3-N and T-N were related to temperature. After mid-April the effluent temperatures remained above 20 degrees C at which time NH_3-N concentration dropped to zero and remained there throughout the rest of the study period. Total nitrogen concentration dropped significantly at this time and remained below 6.2 milligrams per liter.

Reduction of protein nitrogen to ammonia in the storage tank was affected by temperature. The screened wastewater was held for several hours in a tank prior to spraying on the plots. The concentration of NH_3-N and the temperature had a correlation coefficient of 0.65. Ammonia concentration consistently increased in the tank, but the increases were greatest after mid-April. Other forms of nitrogen did not noticeably change after mid-April in this waste stream applied to the three plots.

Removal of all forms of nitrogen on the soil plots was affected by temperatures. Maximum reduction occurred after water temperature reached 20 degrees C. The apparent causes were: the increased concentration of NH_3-N and its loss to the atmosphere by spraying; a reduction of NO_2+NO_3-N by denitrification, and nitrogen uptake by increased microbial and plant growth. Because of the impermeable rock layer below the soil plots, loss of nitrogen into a ground water supply was not possible.

Temperature had an effect on the discharge volume. The most notable effect was when a surface discharge did not occur on hot days when ambient conditions maintained high water temperatures. The absence of a discharge was noted at 9,000 gallons per acre per day with an influent temperature of 19 degrees C and at 10,500 gallons per acre per day with an influent temperature of 25 degrees C. However, a discharge continued at 15,000 gallons per acre per day with effluent temperatures of 30 degrees C. In addition to temperature, wind noticeably influenced the discharge volumes. A prolonged period of freezing temperatures sufficient to stop the discharge because of ice formation did not occur during the study period.

NATIONAL EFFLUENT LIMITATIONS

The effluent limits, for the category "low packinghouse" given in Table 4 are maximum values for an average of daily values within 30 consecutive days or for any one day. All of the treatment systems meet the Best Practicable Treatment (BPT) limits in Table 4 which must be met

Table 4. COMPARISON OF TREATED WASTEWATERS AND EFFLUENT LIMITATIONS (lb/1,000 lb LWK)

Treatment systems	BOD_5		TSS	
	30 day	1 day	30 day	1 day
Plot 5	0.01	0.14	0.05	0.48
Plot 6a	0.02	0.19	0.06	0.34
Plot 6b	< 0.01	<0.01	<0.01	0.02
Plot 7a	< 0.01	0.01	0.01	0.02
Plot 7b	0.02	0.29	0.04	0.40
Effluent limitations				
Best Practical Treatment	0.17	0.34	0.24	0.48
Best Available Treatment	0.04	0.08	0.06	0.12

by July 1, 1977. Plots 6b and 7a meet the Best Available Treatment (BAT) limits in Table 4. The BAT limits must be met by July 1, 1983. In all cases, the BAT limits which were exceeded were maximum day limits. The difference between average discharges and maximum day discharges were ten-fold rather than double.

All maximum day values which exceeded the BAT limits in Table 4 occurred on two sample days when heavy rainfall occurred. On March 20, 1974, a rainfall of 0.71 inches was so intense that the flow measuring devices were unable to record all the discharge. On this day, the waste load discharge from all plots exceeded both the BOD_5 and TSS limits. A heavy rainfall did not occur when samples were collected from Plots 6b and 7a.

All averages calculated for 30-day periods consisted of four or less data points. Except for that period which included March 20, 1974 data, these values meet the BAT limits in Table 4. To obtain a better estimate of the mean, the treatment system 30-day values in Table 4 are averages for entire study periods.

In addition to the parameters in Table 4, there are limits on oil and grease, ammonia, pH, and fecal coliforms. The oil and grease concentrations in the effluents from the plots were in most cases less than 5 milligrams per liter, the limit of accuracy of the analytical method. The maximum value was 8.6 milligrams per liter. Ammonia concentration averages ranged from 0.0 to 4.8 milligrams per liter and maximum values ranged from 0.0 to 7.5 milligrams per liter in the effluents from the plots. The pH levels ranged from 7.5 to 8.5 in the effluents. Additional data on these parameters are in the Appendix. Oil and grease, ammonia, and pH levels in the discharges meet both BPT and BAT limits. The fecal coliform requirement for both limitations is a maximum of 400 mpn (most probable number) per 100 milliliters. Maximum fecal coliform ranged from 8,000 to 320,000 mpn per 100 milliliters in the discharges from the plots. The addition of disinfection facilities will enable the treatment systems to meet this limit.

DISCUSSION

These pilot investigations pointed out needed additions to the treatment system to meet BPT or BAT limitations. Disinfection is needed to meet the fecal coliform requirement in both limitations. Disinfection with chlorine is most economical with a chlorine contact basin having about 1/2 hour detention. To meet BAT limits, the system also needs a means to control maximum daily discharge loads.

During two intense rainfalls when wastewaters were being applied, daily discharges in pounds of BOD and TSS were measured at ten times the average conditions and at five times the the maximum daily limit. The increase in TSS caused the increase in BOD. The suspended solid limit was exceeded when the BOD limit was not exceeded. During these two rainfalls both volume and concentrations increased two- to five-fold over average conditions. During other rainstorms, however, discharge volumes were increased two- to five-fold over the average, but concentrations did not increase and the daily maximum limits were not exceeded. Although both volume and TSS concentration increased before the daily limits were exceeded, either or both can be controlled to meet the BAT limits.

There are a number of liquid-solid separation processes that can be used to reduce suspended solids. Most of these are physical-chemical processes which are mechanically complicated and expensive. Slow sand filtration is a simple process which might be employed. Its area requirements would be a 2 to 5 percent increase over that for the spray runoff plots. The spray runoff system can obtain 80 to 90 percent suspended solids removal and is already available. Since raw wastewater would be sprayed during periods of plant operation, the irrigation system would be available at night and during weekends. However, storage facilities would be needed to use it during these periods.

Storage facilities offer several advantages. They can be designed with a maximum release to meet daily discharge limits. Reduction of suspended solids will occur through sedimentation. When concentrations of pollutants need additional reduction, part of the stored volume can be recycled. Storage facilities can be incorporated in the runoff collection system or can be created by damming natural depressions in the drainage system. Additional storage volume for chlorination can be incorporated at minimum cost. However, the permanent pool should be minimized to prevent algal growth. The storage facilities, like the irrigation plots, should be protected by diversion dikes from rainfall runoff from upslope areas.

The storage requirement would be dependent upon rainfall and temperature conditions and would vary from a few hours to several days. The storage volume would be controlled by the rainstorm selected for design. The data collected in this investigation were insufficient to determine the rainstorm which would result in the maximum waste load discharge. However, indications were that it would be a rainstorm over 0.7 inches. Storage of several times the runoff from a 0.7-inch rain would be a minor part of the total cost of the system.

For meatpackers in the northern part of the country, spraying of wastewater on land during extended periods of freezing weather would be physically impractical. Use of the runoff irrigation system would require storage during these periods.

Use of storage to control maximum daily discharges during heavy rainfalls and to stop application during extended periods of freezing weather suggests the potential for storage and flow equalization of the concentrated raw wastewater. Such storage could result in an anaerobic lagoon. The anaerobic lagoon, which can obtain over 80 percent BOD removal, is the most cost effective treatment process available to the meat industry.

The evaluation of treatment in an anaerobic lagoon followed by spray runoff irrigation was reported on previously.[1] This investigation was carried out at these same facilities over a six month period ending in April 1972. Anaerobic effluent was applied at 8,200 gallons per acre per day which is within the range of hydraulic loadings used in this study. The BOD_5 loading was an order of magnitude less at 4.6 pounds per acre per day, but the NH_3-N and T-P loadings were nearly double at 4.9 and 1.1 pounds per acre per day, respectively. The runoff during the fall and winter study period averaged 56 percent of that applied. Removal efficiencies of both BOD_5 and TSS were in excess of 95 percent. Phosphorus removal was mainly dependent upon loss of flow.

A disadvantage of this sytem was the discharge of NH_3-N which averaged 20 milligrams per liter and exceeded 10 milligrams per liter in 85 percent of the observations. This was due to the high NH_3-N concentration in the anaerobic lagoon effluent which averaged 74 milligrams per liter. The anaerobic lagoon converts most of the protein in meat packing wastewaters to ammonia. Thus, where ammonia limits exist, such as in BAT standards, storage in an anerobic system is not advisable. In mild climates, storage facilities following the spray runoff irrigation system would eliminate the changes of anaerobic conditions and the resulting increase in ammonia. When storage of concentrated wastewater is required by cold weather, the wastewater can be kept aerobic by injection of air at the bottom of the storage facilities. Additional investigation of the spray runoff treatment system is needed to evaluate storage and application techniques.

Cost Estimates

The design and operational information developed in these pilot scale studies was used to make an estimate of cost. A number of assumptions were necessary; those most influencing costs were land prices, operational manpower, power requirements, repairs, and capital recovery. The costs were calculated for a system capable of treating

100,000 gallons per day. A medium size meat packing plant would have a flow of this magnitude or larger.

The screens were selected to handle 175 gallons per minute. The wet well was sized to equalize the output at 100 gallons per minute. Three pumps each with a capacity of 50 gallons per minute were selected. The irrigation system was based on cost for similar systems used for crop production. Material quantities were determined from a layout sketch. Costs for pipe, automated valve, pumps, timers, and chlorination equipment were from catalogs and manufacturer quotes. The discharge storage facilities were sized for a 3-inch rainstorm and the recycle pump and line were sized for 50 gallons per minute. Recycle pumping costs were based on 30 inches of rainfall.

The land requirement was based on a winter application of 6,500 gallons per day per acre. Land cost with clearing and grading was assumed at $1,000 per acre. Land and storage pond cost were amortized at 8 percent over 20 years. Equipment and structures were amortized at 8 percent over 10 years. Manpower estimates were based on 1 hour per day or per rainstorm and at $3.75 per hour. Thirty rainstorms per year were used. Electric power was estimated at 3¢ per KWH and was sufficient for pumping the wastewater and recycled flow against a 100 foot head. Chlorine was priced at $13.50 per hundredweight (cwt). Repairs plus taxes were estimated at 4.5 percent of capital cost per year. Table 5 shows a summary of the estimated costs.

Crites *et al.*[1] have reported capital costs for clearing of land, grading of slopes, planting and construction of the distribution system at $1,006 and $1,500 per acre for two overland flow systems. Operating costs for these two systems range from 5¢ to 10¢ per 1,000 gallons. Land costs for eight other spray irrigation treatment systems ranged from $110 to $800 per acre.

Economic feasibility, especially for the small to medium packinghouse, is controlled by the cost of technical personnel for operation. Thus the limited mechanical equipment and automated operation of this process offer special advantages to these plants.

CONCLUSIONS

The restraints of the variables tested and of the test conditions necessarily qualify the following conclusions:

Table 5. ANNUAL CAPITAL AND OPERATING COST ESTIMATES

Item	Screening, spray irrigation & chlorination	Storage & recycle
Land or storage pond	$1,530	$205
Equipment & structures	2,205	298
ANNUAL CAPITAL COST	$3,735	$503
Manpower	$ 975	$112
Electric power	400	75
Chlorine	90	-
Repairs & taxes	1,350	180
ANNUAL OPERATION COST	$2,845	$367
Annual Capital & Operating	$6,580	$870
$/1,000 gallons treated	$0.25	$0.03

1. Treatment of meat packing wastewaters by screening, spray runoff irrigation, and disinfection can meet 1977 National discharge limitations.

2. Treatment of meatpacking wastewaters by screening, spray runoff irrigation, and disinfection can meet 30-day average limits in the 1983 National discharge limitations. Maximum daily limits for BOD_5 and suspended solids are exceeded when intense rainfall results in large increases in the discharge volume and concentration of suspended solids.

3. The spray runoff irrigation system removed over 90 percent of the total nitrogen applied and discharged an effluent with a maximum ammonia concentration of 4.5 milligrams per liter. In the discharge, nitrate plus nitrite concentrations and temperatures had a significant correlation. Concentrations of all forms of nitrogen discharged noticeably decreased when effluent temperatures were 20 degrees C or more.

4. The spray runoff irrigation system removed between 60 and 90 percent of the quantity of phosphorus applied. Removal was equal to the water lost to seepage and evaporation. Phosphorus concentrations decreased less than 10 percent.

5. The hydraulic and organic loadings had minor effects on removals.

6. Waste load discharges can be controlled by matching hydraulic loadings with weather conditions. For example: loadings of 16,600 gallons per acre per day in the summer and 6,500 gallons per acre per day in the winter resulted in the same waste load discharges which meet 1983 limits for BOD_5 and suspended solids. During hot weather loadings of 9,000 gallons per acre per day with water temperature at 19 degrees C or of 10,500 gallons per acre per day with water temperature at 25 degrees C resulted in no surface discharge.

7. During periods when wastewaters are applied, rainfalls greater than 0.7 inches per day can increase the waste load discharge to as much as ten times average conditions, exceeding the maximum daily value in the 1983 National discharge limitations. Between periods of wastewater application, rainfall can result in a waste discharge from the irrigation plots.

8. Control of the discharge in respect to volume and/or suspended solids concentration is necessary during intense rainfall to meet maximum daily limits in the 1983 National discharge

limitations. Temporary storage facilities with a controlled discharge, and facilities for partial recycle to the irrigation area could offer this control at minimum cost.

9. Cost estimates for a 0.1 million gallons per day plant including screens, wet well, spray runoff irrigation and chlorination were made from the design developed in this pilot scale study. Capital costs, including land, were $30,000. Annual capital and operating costs were $0.25 per 1,000 gallons treated. The addition of a storage and recycle system would increase capital costs by $4,000, and annual capital and operating costs by $0.03 per 1,000 gallons.

RECOMMENDATIONS

A full-scale system on the design and operation developed in this pilot scale study should be demonstrated in a warm climate. The system should include screens, spray runoff irrigation, and chlorination, followed by an auxiliary storage and recycling system to control discharges during rainstorms.

Further development of design and operation of this system should be undertaken in other parts of the country where extended freezing periods occur. The system should include screens, spray irrigation, chlorination and aerated storage. Pumps and pipes should be included for diverting flow both after screening and after irrigation to the storage facilities. This is to permit either control of the discharge during rainfall or of the land application during freezing weather.

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APPENDIX

COMMON STATISTICS ON DATA BASE

Raw Wastewater - 74/01/09 to 74/06/18

Items	Units	No.	Mean	Stan. Dev.	Maximum	Minimum
Temp	^{o}C	24	22.08	6.85	32.00	10.00
LWK	lbs	24	32,101.66	5,363.97	41,550.00	19,980.00
Flow[a]	gpd	24	15,710.83	2,855.89	22,180.00	10,500.00
DO	mg/l	24	2.18	1.83	7.10	0.60
BOD_5	mg/l	22	634.18	199.85	1,075.00	345.00
COD	mg/l	24	1,675.29	438.79	3,120.00	1,044.00
pH		24	7.53	0.25	8.10	7.10
TS	mg/l	24	1,970.66	279.88	2,855.00	1,526.00
TVS	mg/l	24	1,075.79	292.77	2,138.00	731.00
TSS	mg/l	24	498.62	256.60	1,344.00	179.00
Set. S	ml/l	5	12.50	5.40	22.00	8.50
FOG	mg/l	5	139.40	116.88	343.80	56.20
NH_3-N	mg/l	22	13.42	5.61	29.30	6.00
NO_2+NO_3	mg/l	22	0.39	0.32	1.00	0.01
TKN	mg/l	24	87.88	19.73	128.40	57.05
T-P	mg/l	24	9.77	1.84	12.65	5.30
Fecal C	/100	4	2,387,500.00	3,888,987.00	8,200,000.00	120,000.00

[a] Measurable flow was within a 12-hour period.

Note: /100 = most probable number /100 ml.

Spray Influents - 74/01/09 to 74/06/18

Items	Units	No.	Mean	Stan. Dev.	Maximum	Minimum
Temp	°C	24	20.45	6.53	30.00	5.50
DO	mg/l	24	0.81	0.35	1.90	0.20
BOD_5	mg/l	21	374.66	105.63	530.00	180.00
COD	mg/l	24	960.37	244.73	1,914.00	661.00
pH		24	7.37	0.15	7.75	7.10
TS	mg/l	24	1,667.62	432.22	3,504.00	1,324.00
TVS	mg/l	24	649.75	158.27	1,025.00	418.00
TSS	mg/l	23	218.82	85.04	378.00	92.00
Set. S	ml/l	5	1.70	2.22	5.00	0.00
FOG	mg/l	5	67.46	61.15	139.90	14.70
Total N	mg/l	21	105.50	27.73	180.30	55.37
NH_3-N	mg/l	23	32.20	13.19	61.67	11.62
NO_2+NO_3	mg/l	22	0.43	0.64	3.20	0.02
TKN	mg/l	24	73.97	19.68	124.70	18.42
T-P	mg/l	24	7.23	2.42	12.40	2.90
Fecal C	/100	4	1,487,500.00	1,492,411.00	3,700,000.00	450,000.00

Note: /100 = most probable number/100 ml.

Soil Plot No. 5 - 74/01/09 to 74/06/18

Items	Units	No.	Mean	Stan. Dev.	Maximum	Minimum
Temp	°C	16	17.25	5.96	28.00	5.00
Flow On	gpad	21	10,460.19	1,587.67	13,280.00	7,314.00
Flow Off	gpad	21	2,509.95	4,320.53	13,800.00	0.00
DO	mg/l	16	7.82	1.49	11.10	5.60
BOD	mg/l	14	10.00	7.65	26.00	1.00
BOD On	#ad	19	32.66	11.32	51.32	16.16
BOD Off	#ad	14	0.41	0.75	2.71	0.00
BOD Off	#/LWK	14	0.01	0.03	0.14	0.00
COD	mg/l	16	123.31	34.28	194.00	82.00
COD On	#ad	21	81.23	19.69	128.70	44.50
COD Off	#ad	16	4.21	6.47	20.28	0.03
COD Off	#/LWK	16	0.20	0.35	1.08	0.00
pH		16	8.02	0.23	8.35	7.50
TS	mg/l	16	1,350.75	256.03	2,056.00	1,007.00
TVS	mg/l	16	270.68	161.62	800.00	117.00
TSS	mg/l	16	25.18	21.43	86.00	5.00
Set. S.	ml/l	5	0.10	0.22	0.50	0.00
TSS On	#ad	21	17.82	7.08	33.75	8.34
TSS Off	#ad	16	1.04	2.30	8.99	0.00
TSS Off	#/LWK	16	0.05	0.12	0.48	0.00
FOG	mg/l	5	6.14	1.54	8.60	<5.00
T-N	mg/l	13	10.82	6.43	20.74	3.19
NH -N	mg/l	15	1.21	1.33	4.50	0.00
NH -N On	#ad	20	2.83	1.31	5.53	1.01
NH -N Off	#ad	15	0.04	0.08	0.28	0.00
NH -N Off	#/LWK	15	<0.01	0.00	0.01	0.00
NO +NO	mg/l	14	4.04	5.02	15.00	0.14
T-N On	#ad	18	9.42	2.99	16.19	3.72
T-N Off	#ad	13	0.35	0.53	1.71	0.00
TKN	mg/l	16	5.58	2.00	9.80	2.88
T-P	mg/l	16	6.75	1.53	10.80	4.35
T-P On	#ad	21	0.59	0.19	1.04	0.26
T-P Off	#ad	16	0.17	0.26	0.86	0.00
Fecal C	/100	4	100,300.00	149,613.00	320,000.00	1,700.00

Note: gpad = gallons/acre/day
#ad = lbs/acre/day
#/LWK = lbs/1,000 lbs Live Weight Killed
/100 = most probable number/100 ml

Soil Plot No. 6a - 74/01/23 to 74/05/08

Items	Units	No.	Mean	Stan. Dev.	Maximum	Minimum
Temp	^oC	14	15.39	5.65	23.00	5.00
Flow On	gpad	15	9,049.53	1,086.39	10,720.00	7,487.00
Flow Off	gpad	14	4,504.42	4,190.85	14,610.00	0.00
DO	mg/l	14	8.33	1.42	11.30	6.50
BOD_5	mg/l	14	5.84	6.07	25.00	0.80
BOD On	#ad	14	29.49	9.74	44.06	13.52
BOD Off	#ad	13	0.38	0.81	3.04	0.00
BOD Off	#/LWK	13	0.02	0.05	0.19	0.00
COD	mg/l	14	107.71	41.53	196.00	44.00
COD On	#ad	15	73.24	12.08	103.90	58.87
COD Off	#ad	13	5.09	6.45	23.87	0.52
COD Off	#/LWK	13	0.30	0.43	1.52	0.03
pH		14	8.03	0.19	8.40	7.60
TS	mg/l	14	1,269.92	172.91	1,512.00	946.00
TVS	mg/l	14	233.07	98.02	426.00	52.00
TSS	mg/l	14	23.85	20.42	65.00	2.00
Set. S.	ml/l	3	0.00	0.00	0.00	0.00
TSS On	#ad	14	14.35	4.45	20.43	7.26
TSS Off	#ad	13	1.01	1.78	5.35	0.07
TSS Off	#/LWK	13	0.06	0.12	0.34	0.00
FOG	mg/l	3	<5.00	0.00	<5.00	<5.00
T-N	mg/l	12	13.13	10.12	35.18	3.38
NH_3-N	mg/l	14	0.52	1.03	3.90	0.00
NH_3-N On	#ad	15	2.13	0.94	4.14	0.98
NH_3-N Off	#ad	13	0.02	0.05	0.17	0.00
NH_3-N Off	#/LWK	13	0.00	0.00	0.01	0.00
NO_2+NO_3	mg/l	12	8.67	9.88	31.20	0.18
T-N On	#ad	13	8.19	2.09	13.54	5.35
T-N Off	#ad	11	0.53	0.55	1.80	0.01
TKN	mg/l	14	4.20	1.98	9.40	1.10
T-P	mg/l	14	5.89	1.37	7.70	3.00
T-P On	#ad	15	0.54	0.22	1.07	0.24
T-P Off	#ad	13	0.23	0.21	0.77	0.02
Fecal C	/100	3	16,300.00	9,130.00	23,000.00	5,900.00

Note:
gpad = gallons/acre/day
#ad = lbs/acre/day
#/LWK = lbs/1,000 lbs Live Weight Killed
/100 = most probable number/100 ml

Soil Plot No. 6b - 74/05/15 to 74/06/18

Items	Units	No.	Mean	Stan. Dev.	Maximum	Minimum
Temp	°C	5	27.40	3.13	30.00	22.00
Flow On	gpad	6	16,613.33	1,208.48	17,390.00	14,280.00
Flow Off	gpad	6	1,119.41	1,046.51	2,588.00	0.00
DO	mg/l	5	6.78	1.07	8.40	5.60
BOD_5	mg/l	5	5.20	2.48	9.00	3.00
BOD On	#ad	6	47.74	15.49	72.51	32.76
BOD Off	#ad	5	0.06	0.07	0.19	0.01
BOD Off	#/LWK	5	0.00	0.00	0.00	0.00
COD	mg/l	5	103.20	17.93	118.00	77.00
COD On	#ad	6	110.90	25.13	142.10	90.72
COD Off	#ad	5	1.06	0.69	1.98	0.27
COD Off	#/LWK	5	0.03	0.02	0.07	0.00
pH		5	8.30	0.14	8.50	8.10
TS	mg/l	5	1,349.00	197.18	1,587.00	1,092.00
TVS	mg/l	5	179.40	33.41	222.00	142.00
TSS	mg/l	5	16.80	7.25	28.00	10.00
Set. S.	ml/l	1	0.00	0.00	0.00	0.00
TSS On	#ad	6	30.50	13.90	54.53	17.57
TSS Off	#ad	5	0.21	0.21	0.48	0.03
TSS Off	#/LWK	5	0.00	0.01	0.02	0.00
FOG	mg/l	1	<5.00	0.00	<5.00	<5.00
T-N	mg/l	5	3.05	0.47	3.54	2.45
NH_3-N	mg/l	5	0.00	0.00	0.00	0.00
NH_3-N On	#ad	6	5.82	1.65	8.94	4.17
NH_3-N Off	#ad	5	0.00	0.00	0.00	0.00
NH_3-N Off	#/LWK	5	0.00	0.00	0.00	0.00
NO_2+NO_3	mg/l	5	0.32	0.19	0.64	0.15
T-N On	#ad	6	14.57	5.09	22.10	7.59
T-N Off	#ad	5	0.03	0.02	0.07	0.00
TKN	mg/l	5	2.73	0.54	3.25	2.02
T-P	mg/l	5	6.91	0.62	7.40	5.94
T-P On	#ad	6	0.94	0.14	1.13	0.75
T-P Off	#ad	5	0.07	0.05	0.14	0.01
Fecal C	/100	1	8,000.00	0.00	8,000.00	8,000.00

Note: gpad = gallons/acre/day
#ad = lbs/acre/day
#/LWK = lbs/1,000 lbs Live Weight Killed
/100 = most probable number/100 ml

Soil Plot No. 7a - 74/01/23 to 74/03/13

Items	Units	No.	Mean	Stan. Dev.	Maximum	Minimum
Temp	°C	8	13.75	6.14	24.00	4.50
Flow On	gpad	8	6,565.37	951.21	8,085.00	5,463.00
Flow Off	gpad	8	1,154.50	826.72	2,542.00	126.50
DO	mg/l	8	8.85	1.63	11.20	6.10
BOD_5	mg/l	8	6.00	2.72	12.00	3.00
BOD On	#ad	7	21.81	6.74	33.31	12.08
BOD Off	#ad	8	0.06	0.08	0.25	0.00
BOD Off	#/LWK	8	<0.01	0.00	0.01	0.00
COD	mg/l	8	103.25	36.52	176.00	69.00
COD On	#ad	8	52.77	11.37	76.23	38.27
COD Off	#ad	8	0.94	0.70	2.41	0.08
COD Off	#/LWK	8	0.06	0.04	0.15	0.00
pH		8	8.07	0.22	8.30	7.60
TS	mg/l	8	1,252.87	171.90	1,486.00	969.00
TVS	mg/l	8	271.50	182.61	694.00	110.00
TSS	mg/l	8	17.50	9.25	31.00	6.00
Set. S.	ml/l	2	0.00	0.00	0.00	0.00
TSS On	#ad	7	8.72	2.85	13.14	5.12
TSS Off	#ad	8	0.15	0.11	0.30	0.01
TSS Off	#/LWK	8	0.01	0.00	0.02	0.00
FOG	mg/l	2	<5.00	0.00	<5.00	<5.00
T-N	mg/l	7	15.97	7.78	25.76	5.15
NH_3-N	mg/l	8	0.63	0.77	2.17	0.00
NH_3-N On	#ad	8	1.13	0.33	1.63	0.64
NH_3-N Off	#ad	8	<0.01	0.01	0.04	0.00
NH_3-N Off	#/LWK	8	0.00	0.00	0.00	0.00
NO_2+NO_3	mg/l	7	11.05	7.66	22.00	0.65
T-N On	#ad	7	4.97	0.89	6.84	4.13
T-N Off	#ad	7	0.15	0.15	0.45	0.01
TKN	mg/l	8	4.26	1.26	7.00	2.70
T-P	mg/l	8	6.50	1.61	8.70	4.13
T-P On	#ad	8	0.48	0.11	0.66	0.31
T-P Off	#ad	8	0.06	0.04	0.12	0.00
Fecal C	/100	1	26,000.00	0.00	26,000.00	26,000.00

Note: gpad = gallons/acre/day
#ad = lbs/acre/day
#/LWK = lbs/1,000 lbs Live Weight Killed
/100 = most probable number/100 ml

Soil Plot No. 7b - 74/03/20 to 74/06/18

Items	Units	No.	Mean	Stan. Dev.	Maximum	Minimum
Temp	°C	14	22.92	6.13	30.00	9.00
Flow On	gpad	14	14,794.28	360.78	15,460.00	14,350.00
Flow Off	gpad	14	4,570.64	4,949.43	17,710.00	161.00
DO	mg/l	14	6.87	0.96	9.00	5.00
BOD_5	mg/l	13	10.15	13.48	53.00	2.00
BOD On	#ad	13	45.02	14.96	65.88	22.37
BOD Off	#ad	13	0.75	2.13	7.82	0.01
BOD Off	#/LWK	13	0.02	0.07	0.29	0.00
COD	mg/l	14	132.21	36.94	200.00	86.00
COD On	#ad	14	106.19	33.52	147.90	79.12
COD Off	#ad	14	5.25	7.45	28.65	0.26
COD Off	#/LWK	14	0.19	0.28	1.06	0.00
pH		14	8.05	0.27	8.60	7.60
TS	mg/l	14	1,597.85	532.58	2,700.00	1,014.00
TVS	mg/l	14	215.92	99.32	490.00	122.00
TSS	mg/l	14	26.42	30.95	116.00	4.00
Set. S.	ml/l	3	0.33	0.57	1.00	0.00
TSS On	#ad	14	27.97	8.61	46.74	15.32
TSS Off	#ad	14	1.12	2.83	10.93	0.06
TSS Off	#/LWK	14	0.04	0.10	0.40	0.00
FOG	mg/l	3	<5.00	0.00	<5.00	<5.00
T-N	mg/l	11	4.50	1.04	6.20	3.26
NH_3-N	mg/l	13	0.50	1.30	4.30	0.00
NH_3-N On	#ad	13	4.86	1.45	7.52	2.23
NH_3-N Off	#ad	13	0.04	0.10	0.34	0.00
NH_3-N Off	#/LWK	13	<0.01	0.00	0.01	0.00
NO_2+NO_3	mg/l	13	0.78	0.86	3.38	0.15
T-N On	#ad	12	14.25	3.98	22.41	6.62
T-N Off	#ad	11	0.14	0.18	0.53	0.00
TKN	mg/l	13	3.91	0.99	5.70	2.28
T-P	mg/l	14	6.47	1.60	9.20	4.80
T-P On	#ad	14	0.71	0.18	0.96	0.35
T-P Off	#ad	14	0.21	0.21	0.72	0.01
Fecal C	/100	3	31,133.00	21,703.00	47,000.00	6,400.00

Note:
gpad = gallons/acre/day
#ad = lbs/acre/day
#/LWK = lbs/1,000 lbs Live Weight Killed
/100 = most probable number/100 ml

WASTEWATER MANAGEMENT AT HICKMOTT FOODS, INC.

George Tchobanoglous*
Bill Ostertag**
Ed Fernbach***

INTRODUCTION

Hickmott Foods, Inc., is a small independent cannery located in Antioch, California. In the past, the principal items processed were tomatoes, asparagus, and sweet potatoes. The sweet potato and asparagus operations were abandoned after the 1973 and 1974 seasons, respectively, leaving tomatoes as the only commodity to be canned in 1975. Tomatoes are canned in an 80-day operating season during the months of July through October. With the exception of a week or two at the beginning and end of the season, the canning operation is continuous around the clock. In 1971, to meet waste discharge requirements established by the Central Valley Water Quality Control Board, Hickmott Foods undertook a program of wastewater management to clean up its wastewater discharge to the San Joaquin River. Because no municipal system was available to handle the cannery wastes, Hickmott Foods was forced to develop its own waste treatment system or cease to operate.

The purpose of this paper is to summarize the nature and results of water pollution control efforts at Hickmott Foods. Both the in-cannery modifications and the operation of the newly constructed wastewater treatment facility are discussed. Topics to be considered include: (1) waste quantities and water quality objectives; (2) in-plant facilities for waste flow and strength reductions; (3) wastewater treatment facilities including waste characteristics, treatment process operations and costs; and (4) future developments with respect to wastewater management.

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WASTE QUANTITIES AND WATER QUALITY OBJECTIVES

The amounts of waste produced during the 1974 tomato canning season and the discharge requirements imposed by the US Environmental Protection Agency and the Central Valley Regional Water Quality Control Board are considered in this section. To allow valid comparisons to be made with other similar operations, waste production and discharge quantities are also presented on a unit production basis (e.g., pounds per ton of raw material processed).

Waste Quantities

Approximately 1,050 tons of raw mechanically and hand harvested tomatoes are processed daily at Hickmott Foods. Production data for the 1974 season are summarized in Table 1. The 1974 production figures given in Table 1 represent a 21 percent increase in tonnage over the 1973 canning season. Of the daily total, 880 tons of finished product and 170 tons of waste are produced per day.

Wastes from the totamo canning operation at Hickmott Foods are in three forms: (1) solid wastes such as whole tomatoes and tomato skins, seeds, and stems, (2) sludge from the caustic peeling of raw tomatoes, and (3) wastewaters which contain suspended and soluble tomato components, sand, and silt. The quantities and characteristics of these wastes are shown in Tables 2 and 3.

Of the 170 tons of tomato components that go to waste each day (see Table 2), 39 tons are hauled away as solids for cattle feed, 120 tons of caustic tomato sludge are generated per day from the dry peeling operation, and approximately 11 tons per day of raw product is lost in the wastewater flow stream.

The characteristics of the wastewater that would have to be treated if the peeling sludge were to be dumped into the plant sewer, as was the practice before the 1974 canning season, is also shown in Table 3. Presently, the peeling sludge is isolated and trucked away for land disposal. Studies are underway to determine the feasibility of recycling this sludge to recover much of this lost food value (see section Dealing with Future Developments).

Discharge Requirements

Hickmott Foods was given its first set of discharge requirements in 1971 and was issued an NPDES permit on January 1, 1975. These requirements are shown in Table 4. Based on the requirements set forth

Table 1. PRODUCTION DATA FOR 1974 TOMATO CANNING SEASON[a]

Item	Value
Raw product delivered	
Daily average, tons/day	1,050
Season total, tons	59,000
Finished products	
Peeled tomatoes, tons/day[b]	500
Tomato products, tons/day[b]	380
Total, tons/day[c]	880
Raw product loss in processing	
Quantity, tons/day	170
Percentage, percent	16

[a] Averages for full 24-hour operating day.

[b] Calculated from pack reports.

[c] Caluclated from pack reports, standard case per ton conversion factors and estimated loss in evaporation and waste.

Table 2. WASTE GENERATION DURING 1974 TOMATO CANNING SEASON

Item	Value		Unit value[a]	
	With peel recovery[b]	Without peel recovery[c]	With peel recovery[b]	Without peel recovery[c]
Solid wastes, tons/day	39	37	74	70
Peeling sludge at 7% solids, tons/day[d]	120	0	228	0
Loss of tomato in wastewater, tons/day[e,f]	11	133	21	253
Total loss of raw product as waste, tons/day	170	170	323	323

[a] Unit production values are on a gal./ton or lb/ton of raw tomato basis (whichever is applicable).

[b] Current method of operation.

[c] Predicted quantities based on measured values for peeling sludge COD, suspended solids, and flowrate.

[d] 32,400 gal./day

[e] Based on waste characteristics given in Table 3.

[f] 1.0 pound of whole tomato yields 1.3 pounds of COD (COD of whole tomato = 73,000 mg/l, TSS of whole tomato = 55,000 mg/l).

Table 3. WASTEWATER CHARACTERISTICS DURING 1974 TOMATO CANNING SEASON

Item	Value		Unit value[a]	
	With peel recovery[b]	Without peel recovery[c]	With peel recovery[b]	Without peel recovery[c]
Wastewater flowrate, mgd	1.14	1.17	1,090	1,114
Total chemical oxygen demand, mg/l	3,000	5,500[d]	27	51[d]
Total biological oxygen demand, mg/l	1,300	2,400	12	22
Total organic carbon, mg/l	1,100	2,000	10	18
Total suspended solids, mg/l	1,000	1,200	9	11

[a] Unit production values are on a gal./ton or lb/ton of raw tomato basis (whichever is applicable).

[b] Current method of operation.

[c] Predicted quantities based on measured values for peeling sludge COD, suspended solids, and flowrate.

[d] Includes peeling sludge.

[e] 1.0 pound of peeling sludge yeilds 1.0 pounds of COD (see Table 2).

Table 4. WASTE DISCHARGE REQUIREMENTS[a]

Constituent	Value	
	30-day average	Daily maximum
Process wastewater		
Daily flow, mgd		1.3
BOD_5, lbs/day	800	1,890
Total suspended solids, mg/l	75 (50)	125 (75)
Total suspended solids, lbs/day	820	1,360
Settleable matter, ml/l	0.2 (0.5)	0.5 (1.0)
Oil and grease, mg/l	10	15 (10)
pH		6.5-8.5[b]
96-hour bioassay, % survival		
Minimum, any one bioassay	70 (100)	
Median, three or more consecutive	90	
Cooling water		
COD, mg/l		50[c]
Temperature, °F		20° above background[d]

[a] Effective January 1, 1975, previous requirements shown in parenthesis.

[b] Range.

[c] Average value above background.

[d] Combined process and cooling water discharge shall not exceed 20°F above the temperature of the San Joaquin River or 80 to 90°F.

in Table 4, Hickmott Foods must remove 94 percent of the BOD_5 and 91 percent of the total suspended solids from its wastewaters before discharge.

WASTE MANAGEMENT IN CANNERY

Significant reductions in the wastewater flowrate and strength have been accomplished by modifying various operations within the cannery production area. These changes and their impact are discussed in this section.

Wastewater Flow Reduction

The two principal components of the wastewater produced during the 1973 and 1974 tomato canning seasons are the process water and the water from the evaporators and retorts (see Table 5). Water used in the production process is derived primarily from the domestic water supply of the City of Antioch; whereas, the water used to cool the evaporators and retorts is filtered San Joaquin River water.

Several steps were taken between 1973 and 1974 to reduce the quantity of water used by the cannery and to reduce the wastewater flowrates. The cooling water was analyzed and found to be suitable for direct discharge to the river (COD less than 50 milligrams per liter) after cooling. Eliminating the cooling water from the waste stream reduced the flow requiring treatment from 3.1 million gallons per day to 1.14 million gallons per day, while cannery production increased 20 percent.

The installation of four dry peel removal machines reduced the total water needed for peeling from 306 to 124 gallons per minute. The quantity of peel sludge produced dropped from 150 to 25 gallons per minute while cannery production increased 20 percent. This reduced amount of peeling sludge now made it possible to isolate this material and process it separately.

All low pressure-high volume washdown hoses were removed and a high pressure hose system with nozzles that shut off upon release was installed. This change resulted in a washdown flow reduction of at least 80 gallons per minute (see Table 5). As low pressure hoses are usually left to run on the floor, the reduction was probably somewhat larger. Some employees objected to the use of the high pressure spray, as it is harder to control, but eventually became accustomed to using

Table 5. DAILY WATER USAGE DURING 1974 CANNING SEASON AND PERCENT REDUCTION DATA OVER 1973 CANNING SEASON[a]

Item No.	Description of Source	1974 Flowrate, gpm	Percent Reduction over 1973
	Process Wastewater[b]		
1	Seals on sump pump (1/2" line, 2 @ 8.8 gpm)	18	-
2	Bin washing system (2 @ 17.5 gpm)	35	-
3	Incoming product sprays 2 @ 10 gpm)	20	-
4	Small tomato dropout fluming to product tables	35	-
5	Make-up water to lye peelers (2 @ 10 gpm)	20	-
6	Rinse tanks after peeling (2 @ 50 gpm in 1973)	0[c]	100
7	Dry scrubbers (4 @ 6 gpm) (1 @ 50 gpm in 1973)	24[b]	52
8	Rinse water on roller washers (4 @ 20 gpm) (4 @ 35 gpm in 1973)	80[d]	43
9	Belt lubrication and cleaning	50[e]	-
10	Can washers, 7 peeling, 3 product (10 @ 18 gpm)	180[h]	-
11	Kettles (1" line, 1 @ 30 gpm)	30	-
12	Washdown lines, low pressure (4 @ 35 gpm in 1973)	0[c]	100
13	Washdown lines, high pressure (6 @ 10 gpm)	60[f]	-
14	Can cooling, outside coolers (7 @ 35 gpm)	245	-
15	Cooling water, vacuum pumps (3 @ 8.8gpm)	27	-
	TOTAL WASTEWATER GENERATED, gpm (1126 gpm in 1973)	800	29
	Evaporators & Retorts[g]		
16	Evaporator No. 1	550	-
17	Evaporator No. 2	350	-
18	Retorts	100[h]	69
		1,000	17
	Fluming Water[i]		
19	Tomato fluming	600	

[a] Based on individual flowrate measurements during 1973 and 1974 peak production periods.

[b] All process wastewater must be treated by the wastewater treatment facilities except Item 7. See section on Dry Peeling.

[c] Eliminated from 1973 operation.

[d] Reduced by lowering spray pressure.

[e] To be reduced in 1975 by shortening belt runs.

[f] Nozzles shut off when not in hand of operator.

[g] Water from evaporators and retorts is discharged directly to river after passing through cooling tower.

[h] Retort water is recovered and used for can washing.

[i] Fluming water is recycled internally. Make-up water is obtained from Items 3 & 4.

these nozzles. No degradation in the quality of the product or plant sanitation was observed.

Cooling water discharge was reduced by 200 gallons per minute by reusing the retort cooling water for can washing. Besides reducing the amount of water to be cooled before discharge to the river, the amount of river water that must be filtered and chlorinated for use in the can washing system was also reduced.

Organic Waste Reduction

The quantity of raw tomato constituents present in the process wastewater was reduced from the 1973 to 1974 season by modifications in the peeling operation and floor waste management.

Dry Peeling---The installation of four dry peel removal machines and modifications in the operation of the caustic peelers has resulted in a reduction in chemical usage and the quantity of waste generated that must be treated. This has been accomplished with no deterioration in product quality. Dry caustic peeling, using rotating rubber discs to mechanically rub peel from tomatoes dipped in sodium hydroxide, replaced the conventional water rinse peeling operation. Effective peeling was obtained with this method while reducing the concentration of caustic in the peelers. Operational data for the peelers are summarized in Table 6 for the 1973 and 1974 seasons. Through a combination of reducing the peeler speed (resulting in more tomatoes per bucket but a longer contact time with the caustic per tomato) and using mechanical peeling, it was possible to use a caustic solution of 7 to 10 percent in 1974 as opposed to an 18 to 20 percent solution in 1973. This mode of operation resulted in a reduction in caustic usage (6.9 pounds per ton in 1974 as opposed to 11.7 pounds per ton previously) and reduced chemical requirements for neutralization of the resulting wastewater. As discussed in a later section reducing the pH value of the caustic sludge can also make the possibility of product recovery more practicable.

Dry caustic mechanical peeling requires about 80 gallons of potable water per ton of tomatoes as opposed to 720 gallons per ton using conventional methods. The 80 gallons per ton which amounted to 24 gallons per minute of caustic sludge in the Hickmott Foods operation is a small enough volume that it can be disposed of in a land spreading operation. The characteristics of the caustic sludge generated during 1974 are summarized in Table 7 in the following section. The exclusion of this sludge from the waste stream to the water pollution control plant reduced the BOD_5 load on the facility by 46 percent.

Table 6. SUMMARY DATA ON CAUSTIC TOMATO PEELING OPERATION AND ACID USAGE AT HICKMOTT FOODS, INC.

Parameter	Season		Reduction 1974 over 1973, %
	1973	1974	
Number of caustic peelers	4	4	
Peeler spped, buckets/min, each	40-44	24-28	
Loading rate, tons/min, each	0.33	0.33	
Caustic solution in peeler, %	18-20[a]	7-10[a]	
Total season throughput, tons	29,000	35,000	
Caustic usage, tons	198[b]	121[b]	
Unit caustic usage, lbs/ton	11.7	6.9	41
Acid usage, tons	71[c,d]	53[c,e]	
Unit acid usage, lbs/ton	4.9	3.0	39[e]

[a] Estimated average from operator titrations.

[b] 50% sodium hydroxide used.

[c] 93% sulfuric acid used for neutralization of wastewater at treatment facilities.

[d] All caustic peeling sludge entered treatment system.

[e] Only a small portion of the caustic sludge entered the waste treatment system. Tighter restraints imposed on neutralization system offset expected acid usage reduction.

Table 7. INFLUENT AND EFFLUENT WASTEWATER CHARACTERISTICS DURING THE 1974 TOMATO CANNING SEASON

Constituent	Normal operation without peeling sludge		With peeling sludge in waste stream[a]	
	Influent[b]	Effluent[c]	Influent[b]	Effluent[c]
Total flow, gpm		800		825
Total flow, mgd		1.14		1.18
Suspended solids, total, mg/l	1,000	60	1,200	60
Volatile, mg/l	400	20	-	20
Fixed, mg/l	600	40	-	40
BOD_5, total, mg/l	1,300	30	1,800	30
Soluble, mg/l	1,100	20	1,200	20
TOC, total, mg/l	1,100	50	1,600	60
Soluble, mg/l	900	30	-	-
COD, total, mg/l	3,200	120	5,500	200
Soluble, mg/l	2,700	90	5,000	150

[a] Values based on limited operational data obtained during periods when peeling sludge was discharged to waste stream.

[b] After screening with a 20-mesh vibrating screen.

[c] After biological treatment.

As shown on Table 3, if the peeling sludge had not been handled separately the BOD_5 of the wastewater in 1974 would have been 2,400 milligrams per liter as opposed to the 1,300 milligrams per liter actually measured.

Floor Waste Management---Because tomatoes are, for the most part, a water soluble fruit, the longer they remain on the cannery floor or in a wastewater conveyance facility, the more the tomato solids and juices contribute to the soluble COD and BOD_5 of the wastewater. If processing wastes are picked up in solid form they can be fed to livestock or at least trucked to disposal as solid wastes. Manual collection of large solid tomato parts was stressed during the 1974 season. Gratings on all floor drains were also bolted down. Reliable solid waste per ton data were not available for the 1973 season but it is estimated that considerably more solid waste was trucked to cattle feed during the 1974 season. This is waste that does not reach the treatment facility as fine suspended matter or soluble organics.

WASTEWATER TREATMENT FACILITIES

Construction of wastewater treatment facilities began in 1973 and after modification of the original design, the current plant was operational for the 1974 canning season. The purpose of this section is, therefore, to present and discuss the wastewater treatment system used at Hickmott Foods. Topics to be considered include: (1) the characteristics of the wastewater to be processed, (2) the treatment process flowsheet, (3) the individual unit operations and process comprising the treatment system, and (4) the associated treatment costs.

Wastewater Characteristics

Eight-hour composite samples of the wastewater were taken weekly during the 1974 operating season. Constituent concentrations determined for both the raw wastewater and treatment process effluent are reported in Table 7. As shown, the COD of the raw wastewater is about 2.3 times the BOD_5 as compared to 2.5 for most domestic wastes. The BOD_5 values shown in Table 7 are those obtained from the BOD_5 test as delineated in Standard Methods.[1] The BOD_5 values were found to increase by about 20 to 25 percent when the bacterial seed for the test was acclimated to tomato peeling sludge. It was also found that the BOD_5 value was approximately 55 to 65 percent of the ultimate BOD value when using acclimated seed. If it is assumed that the reported BOD_5 value (1,300 milligrams per liter) is about 80 percent of the acclimated value and that the acclimated value is 60 percent of the ultimate BOD value, the ultimate value would be computed to be 2,710 milligrams per liter. This compares reasonably well with the COD value (3,000 milligrams per liter). The total organic carbon values are slightly less than the conventionally determined BOD_5 values. For this particular tomato waste, the TOC can be used as a quick indication of the BOD_5.

Over 50 percent of the influent suspended solids are fixed solids such as clay, silt and sand. Because separate dirt removal facilities are not used, all of the dirt, save what is settled out in the dump tank or can be shoveled into a dump truck, is pumped to the treatment process. The impact of this inert material is discussed in the sections dealing with nutrient requirements and sedimentation basin performance.

Treatment Process Flowsheet

Hickmott initiated the design and construction of wastewater treatment facilities in 1972. In the original design, large solids were removed with vibrating screens before the wastewater was sent through a series of centrifugal screen separators. From there, the waste was neutralized and discharged into a two-stage aerated lagoon system which was mixed and aerated by circulating the lagoon contents through pressurized tanks. Sedimentation facilities were not included in the original design. It was soon realized by Hickmott Foods and their first consultant that this system could not meet discharge requirements. Unfortunately the wastewater had not been characterized adequately before the plant was constructed. Because the centrifugal screens were overloaded hydraulically, it was not possible to produce a tomato sludge thick enough to make hauling feasible. Although the treatment process did reduce the soluble organic content of the waste, because liquid-solids separation facilities were not provided, the suspended solids concentration in the effluent was as high or higher than the original waste stream. In addition, the cooling water discharge was part of the waste flow. This put an additional hydraulic loading on the treatment plant and reduced the detention time in the treatment system.

A new consultant was retained by Hickmott Foods, the treatment flowsheet was modified, and the necessary construction was completed in time for the 1974 operating season.[2] The modified process flowsheet currently in use in shown in Figure 1. The vibrating screens, neutralization facilities and the effluent disposal portion from the original flowsheet were retained. The two lagoons have been converted to aeration and sedimentation basins. Sludge is recycled from the sedimentation basins back to the aeration basin. Cooling water is treated separately but is discharged through a common outfall. A plan view of these facilities is shown in Figure 2 and pictorial views are

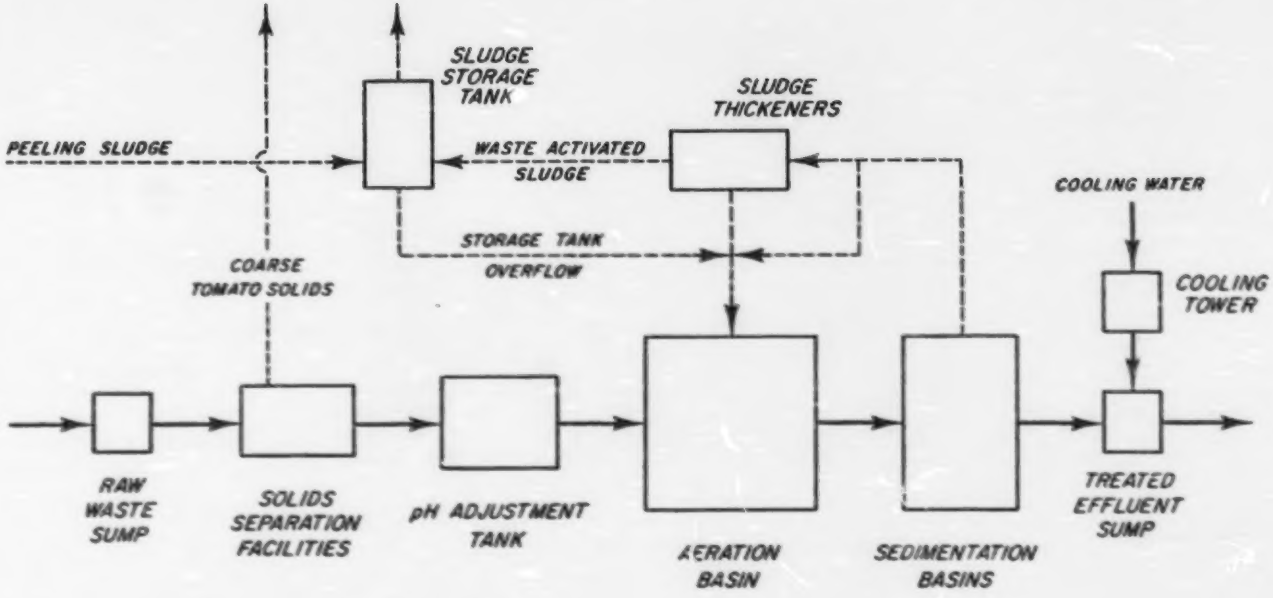

SLUDGE STORAGE TANK
SLUDGE THICKENERS
PEELING SLUDGE
WASTE ACTIVATED SLUDGE
COOLING WATER
STORAGE TANK OVERFLOW
COARSE TOMATO SOLIDS
COOLING TOWER
RAW WASTE SUMP
SOLIDS SEPARATION FACILITIES
pH ADJUSTMENT TANK
AERATION BASIN
SEDIMENTATION BASINS
TREATED EFFLUENT SUMP

Figure 1. Flowsheet for wastewater treatment process.
(Put into operation in 1974.)

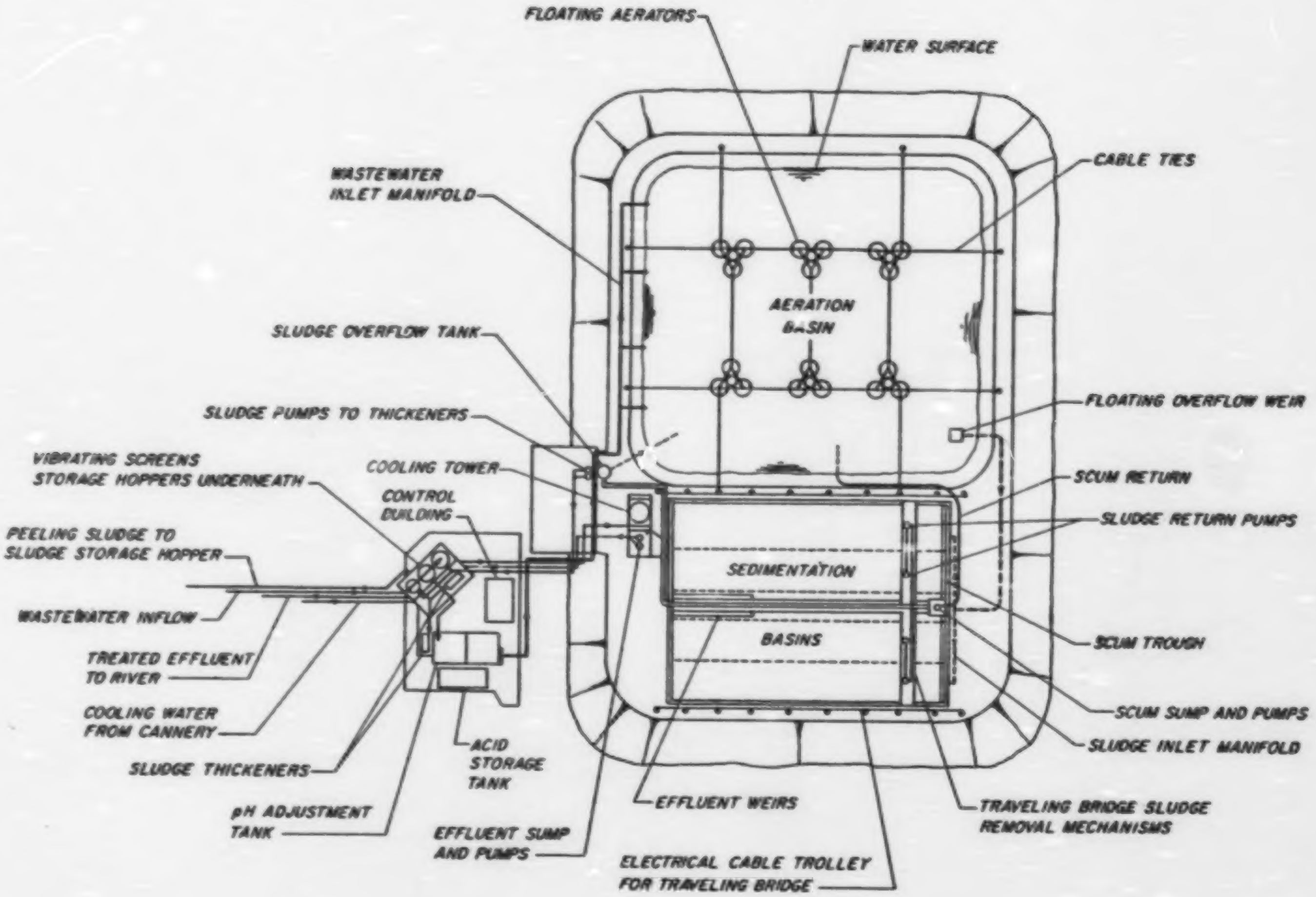

FLOATING AERATORS
WATER SURFACE
CABLE TIES
WASTEWATER INLET MANIFOLD
AERATION BASIN
SLUDGE OVERFLOW TANK
FLOATING OVERFLOW WEIR
SLUDGE PUMPS TO THICKENERS
VIBRATING SCREENS STORAGE HOPPERS UNDERNEATH
COOLING TOWER
SCUM RETURN
CONTROL BUILDING
SLUDGE RETURN PUMPS
PEELING SLUDGE TO SLUDGE STORAGE HOPPER
SEDIMENTATION
WASTEWATER INFLOW
BASINS
SCUM TROUGH
TREATED EFFLUENT TO RIVER
COOLING WATER FROM CANNERY
SCUM SUMP AND PUMPS
SLUDGE INLET MANIFOLD
SLUDGE THICKENERS
ACID STORAGE TANK
EFFLUENT WEIRS
TRAVELING BRIDGE SLUDGE REMOVAL MECHANISMS
pH ADJUSTMENT TANK
EFFLUENT SUMP AND PUMPS
ELECTRICAL CABLE TROLLEY FOR TRAVELING BRIDGE

Figure 2. Plan view of wastewater treatment facilities.

presented in Figure 3. The performance of each of the unit operations and processes is discussed below.

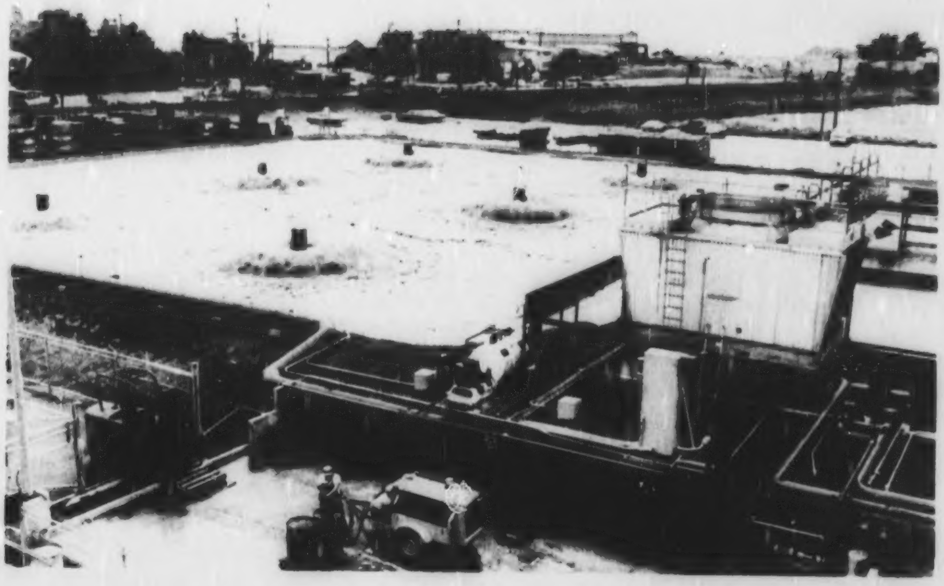
Unit Operations and Processes

The individual unit operations and processes that comprise the treatment system of Hickmott foods are considered in this section. They include: (1) raw solids separation, (2) neutralization and nutrient addition, (3) activated sludge process, (4) sedimentation, (5) activated sludge waste solids thickening, (6) sludge disposal, and (7) cooling water treatment.

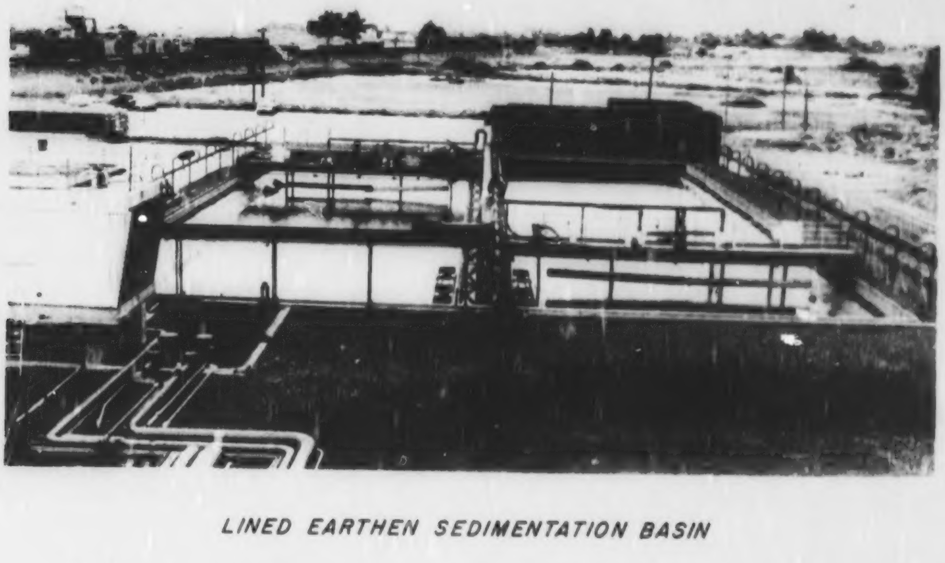
Raw Solids Separation---The raw solids separation facilities consist of two 60-inch diameter two-stage vibrating screens. The screens are cleaned by the vibratory motion of the screens and the rotating spray headers. Approximately five tons per day of raw tomato solids, twigs and cans are removed from the waste stream using 20-mesh stainless steel screens. About 50 percent of the total suspended matter that reaches the treatment facility is removed with the screens. This material is discharged directly into a storage hopper. Screened solids are trucked to nearby ranches for cattle feed.

Neutralization and Nutrient Addition---Before further treatment, the wastewater pH is adjusted to between 6.5 and 8.5. Neutralization is accomplished in a two compartment tank. The detention time in each compartment at average flow is about 20 minutes. Sulfuric acid addition to each compartment is controlled with a pH probe and individual controllers are used for rough and fine pH adjustment. Sulfuric acid usage during the 1973 and 1974 canning seasons is shown in Table 6. The acid dosage ranged from 20 to 60 milligrams per liter of H_2SO_4.

Nitrogen and phosphorus as well as many trace elements are essential to the growth of microorganisms in the aeration basin.[3] The estimated nitrogen and phosphorus requirements as well as the range in concentrations of these nutrients measured in the tomato wastewater are reported in Table 8. During most of the canning season, the nitrogen and phosphorus levels in the wastewater are near the upper end of the ranges shown in Table 8. However, during the early part of the canning season when tomatoes are harvested from the southern portion of California's Central Valley, nutrients must be added because the sandy soils in this area contain few, if any, adsorbed nutrients. As Hickmott Foods has no prior removal of sand, silt and clay, the NH_4^+ and PO_4^{-3} associated with the inorganic solids serve a major nutrient source. As the clay and silt content of the soil increases as harvesting moves up the Central Valley, nutrient addition is not required. The reduced nitrogen and phosphorus levels also occur at the time of process start-

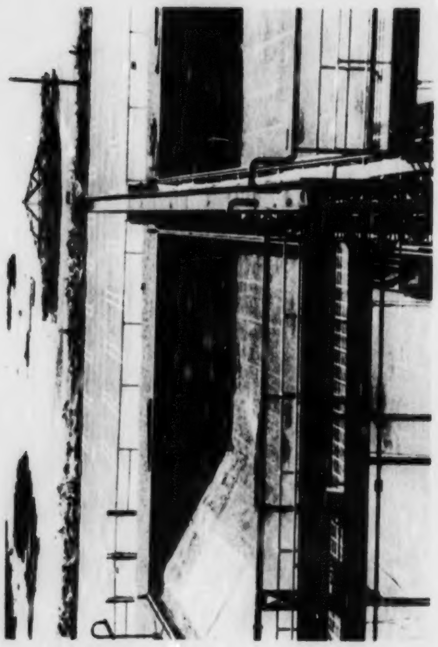


AERATION BASIN WITH SURFACE AERATORS IN OPERATION

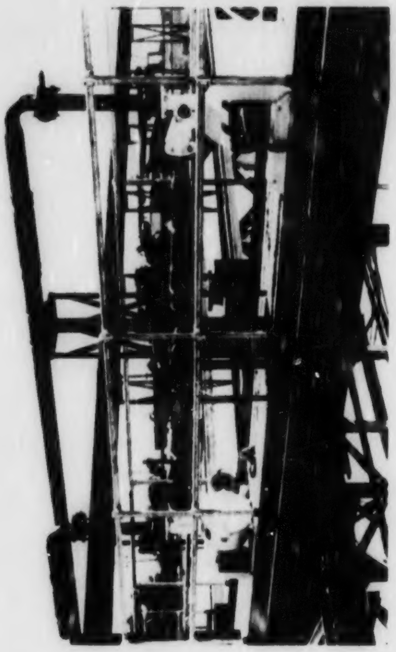


LINED EARTHEN SEDIMENTATION BASIN

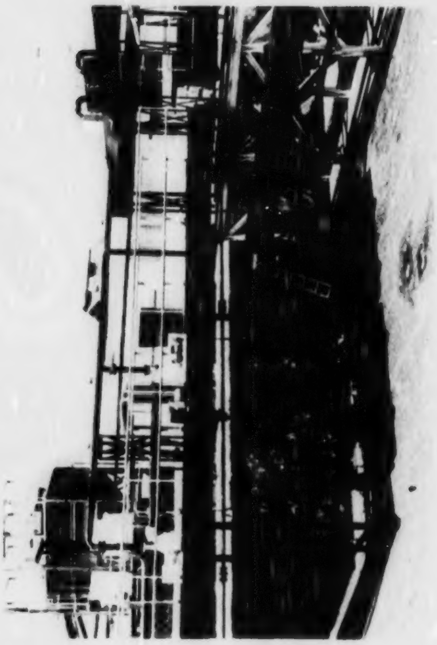
Figure 3. Photographs of wastewater treatment facilities. (Continued on next page.)



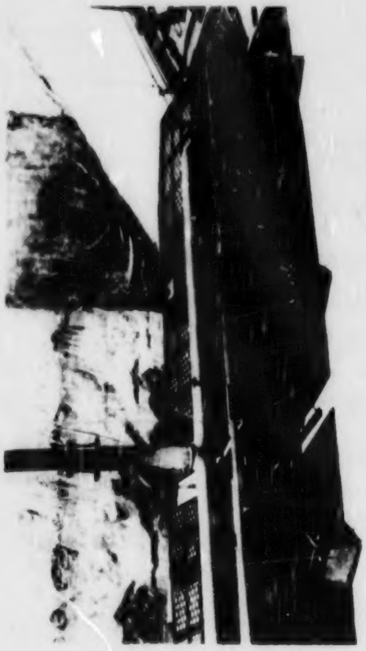
CENTRAL SLUDGE TROUGH AND TRAVELING BRIDGE SLUDGE REMOVAL MECHANISMS



SLUDGE PUMPS ON TRAVELING BRIDGE



TRAVELING BRIDGE, SLUDGE PICKUP ASSEMBLY, AND EFFLUENT TROUGH



DETAIL OF SLUDGE PICKUP ASSEMBLY

Figure 3 (continued). Photographs of wastewater treatment facilities.

Table 8. NUTRIENT REQUIREMENTS ACTIVATED SLUDGE PROCESS AND QUANTITIES AVAILABLE IN WASTEWATER FROM TOMATO CANNING OPERATIONS

Constituent	Amount required, lb/day	Amount available in wastewater	
		Conc., mg/l	Total,[a] lb/day
Total Kjeldahl nitrogen as N	417[b]	20-90	190-856
Total phosphorus as P	85[c]	4-12	38-114

[a] Average dialy flor of 1.14 mgd.

[b] 12.4% of the total daily volatile solids production in activated sludge process during normal operation.

[c] 2.5% of the total daily volatile solids production by activated sludge process during normal operation.

up. The presence of filamentious organisms (sludge bulking) and the absence of the protein foam usually present on top of the aeration basin were observed until supplemental nutrients were added. When nitrogen and phosphorus are added in the form of aqueous ammonia and phosphate fertilizer until traces of ammonia, nitrate or phosphate are observed in the effluent bulking is eliminated and the surface foam reappears.

Activated Sludge Process---After neutralization, the wastewater flows into the aeration basin where waste tomato organics are converted to bacterial cell material. The physical configuration of the aeration basin is shown in Figure 2. Six 60-horsepower floating high-speed aerators are used to provide oxygen to the process and to mix completely the contents of the basin. Normally all six aerators are operated continuously. However, to save power costs the units could be turned off and on as the demand warranted. A Hypalon liner is used to prevent erosion by the aerator turbulence. Biological solids are separated from the flow stream in sedimentation basins and are returned to the aeration basin. The net biological solids produced each day are removed daily from the treatment system.

The physical characteristics of the aeration basin and the activated sludge process operational parameters are reported in Table 9. As shown, the process can be classified as extended aeration activated sludge (mean cell residence time typically greater than 12 days). With the existing aeration and mixing capacity, it was possible to maintain mixed liquor suspended solids concentrations ranging from 9,000 to 15,000 milligrams per liter while holding a dissolved oxygen concentration of 4 to 5 milligrams per liter. High solids concentrations, however, may result in problems in the design and operation of sedimentation facilities. This subject is discussed further in the following section.

The observed advantages of this process in terms of process performance and reliability are as follows.

1. Because of the low food-microorganism ratio, the process is less susceptible to upsets caused by high organic shock loadings.

2. Becuase high levels of dissolved oxygen can be maintained, higher forms of microorganisms are present and a very clear effluent is produced (4 feet on a standard secchi disc).

3. Because the process can be operated in the extended aeration mode, a sludge is produced that settles well and carries down colloidal silt and clay particles.

Table 9. PHYSICAL CHARACTERISTICS AND OPERATIONAL PARAMETERS FOR THE ACTIVATED SLUDGE PROCESS MEASURED DURING 1974 TOMATO CANNING SEASON

Item	Range	Average
Aeration basin characteristics		
Volume, mg		1.10
Aeration time, hrs.		24
Aerators, number		6
Aerators, horsepower (6 @ 60 hp/aerator		360
Oxygen transfer rate,[a] lb O_2/hp-hr	2.0-4.5	3.0
Mixing, hp/1,000 gals.		0.33
Dissolved oxygen concentration, mg/l	2.0-6.0	4.5
Process operational parameters		
MLSS[b] under aeration, mg/l	8,000-15,000	10,000
Percent volatile	40-75	55
F:M (food to microorganism ratio),		
lb BOD_5/lb MLVSS[c]		0.28
lb COD/lb MLVSS[c]		0.49
Mean cell residence time,[d] days	8-20	12
Yield coefficient,		
lb cells/lb BOD_5	0.30-0.60	0.58
lb cells/lb COD	0.13-0.26	0.24
Sludge production,[e] lb VSS/day	3,700-7,400	

[a] Calculated on the basis of COD satisfied (see Table 7).

[b] Mixed liquor suspended solids.

[c] Mixed liquor volatile suspended solids.

[d] Calculated on basis on cells in aeration basin only.

[e] Sludge production varies with mean cell residence time.

4. Because the process can be operated in the extended aeration mode, nutrient requirements are reduced.

The process was monitored with daily observations of the bacterial population because it was found that process changes and stress conditions could be observed before they would effect overall treatment efficiency. When the process is operating normally, the bacterial population is composed primarily of small bacteria with large numbers of stalked ciliates (Vorticella) and many free swimming ciliztes and rotifers (Philondina). The presence of these higher forms was used as an indication that the process was operating properly. The following conditions would cause the disappearance of the higher forms.

1. Dissolved oxygen levels below 3.0 to 4.0 milligrams per liter--It is possible that with high mixed liquor solids the dissolved oxygen transfer efficiency is impaired at lower concentrations.

2. High organic loadings--When the process was in the dispersed growth phase, it was observed that the higher forms did not compete as well as the simpler bacterial forms.

3. Toxic substances or nutrient deficiencies--These problems were also found to effect the higher forms.

4. pH control--If the pH control system was turned off, it was observed that the ciliates and rotifers could not adapt to pH fluctuations and would soon disappear.

Filamentious bacteria were not present under normal operation unless the following conditions prevailed.

1. Nutrient deficiencies--When the supply of nitrogen and phosphorus was below that required by the process for extended periods of time, filaments would begin to predominate and cause sludge bulking.

2. Low dissolved oxygen levels--When dissolved oxygen concentrations remained below 2.0 milligrams per liter for extended periods, the population of filamentious organisms would rise.

Sedimentation Facilities---The sedimentation facility was constructed in an existing pond which was once used as an aerated lagoon. Modifications to the old lagoon included the addition of concrete and walls, the fabrication of an inlet manifold, center rail support structure and effluent weir troughs, and the installation of two electric motor-driven traveling sludge removal mechanisms. The dirt basin is lined with Hypalon. Neoprene rubber skirts are used to push sludge to the pick-up points on each bridge (see Figure 3).

Sedimentation basin loadings and performance characteristics are summarized in Table 10. The high mixed liquor suspended solids levels and the settling characteristics of this sludge result in a solid-liquid separation process that is solids limited. The activated sludge process could not be operated in the extended aeration mode or with the high mixed liquor suspended solids levels with a smaller sedimentation basin.

The traveling bridge sludge return mechanism allows for the flexible operation of the sedimentation facility. The sludge return rate can be varied by adjusting the self-priming sludge pumps on each bridge. Under normal operation, the bridge travel rate is 5 feet per minute. Return sludge is discharged into an overhead trough and flows by gravity back to the aeration basin or is pumped to the sludge wasting facilities. Two profiles of the return sludge concentration as a function of distance along the basin are shown in Figure 4. Because each profile is for a different sludge return rate, the degree of thickening obtained is also illustrated. As shown in Figure 4, the return sludge concentration remains constant until the pick-up mechanisms reaches the effluent end of the basin and then rises sharply. In this case, the bridge is moving through the sludge blanket faster than the sludge is being pumped. Some of the sludge passes over the pick-up head and upon approaching the effluent end, the thickened sludge is squeezed against the end wall. In such a situation, the return rate should be increased or the bridge travel speed reduced to obtain a more uniform return sludge profile.

Because the sedimentation facility was solids limited hydraulic surges caused the transfer of solids from the aeration basin into the sedimentation basin at a rate much faster than they could be settled and pumped back to the aeration basin. If the surges were of short duration, the sludge return facilities would catch up with the rising sludge blanket. However, if the duration of the flow surge was too large, a deterioration in effluent quality would ultimately result.

As noted previously, Hickmott Foods has no sand, silt, and clay separation from its wastewaters. During periods of stable process operation, it was observed that the small colloidal clay particles present in the wastewater are carried down with the bacterial flow. But during periods when the sludge is not settling well when the bacterial process is in the log growth phase (such as when the cannery is starting up after being down) some of the clay particles escape into the effluent. When this occurred, the ratio of volatile to total suspended solids in the final effluent would decrease. This ratio was as low as 0.25 when the corresponding total effluent suspended solids was 75

Table 10. SEDIMENTATION BASIN CHARACTERISTICS, LOADINGS, AND PERFORMANCE DATA

Item	Value
Basin characteristics	
Number	2
Average surface area, sq ft, each	4,080
Liquid depth, ft	6.5
Volume, mg, each	0.20
Detention time at 2.28 mgd, hr, total	4.2
Design loadings	
Hydraulic loading rate including 100% recycle flow, gal./sq ft/day	280
Solids loading rate including 100% recycle flow lb/sq ft/day	23
Weir loading, gal./day/linear ft	11,400
Return sludge,	
Flowrate, gpm	800
Percent of average flow	100
Effluent quality	
Suspended solids,	
Range, mg/l	9-75
Average, mg/l	60
Volatile fraction	33
Secchi disc readings, ft	1-4

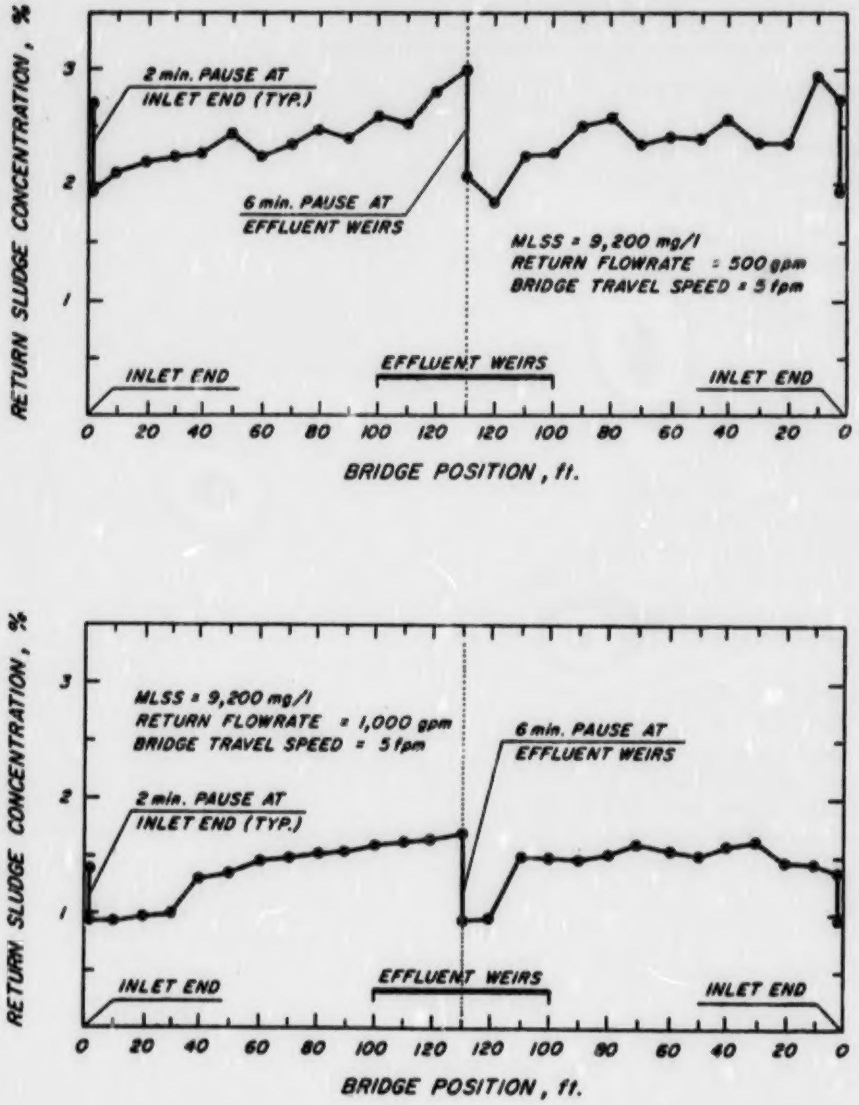


Figure 4. Return sludge concentration profiles.

milligrams per liter (normal value of volatile to total suspended solids ratio in mixed liquor was approximately 0.55).

Activated Sludge Waste Solids Thickening---For process control the bacterial cells grown each day must be wasted. Wasting is accomplished by pumping returned sludge through a three-stage centrifugal screen thickenng operation. In the centrifugal screen, the sludge is pumped through a distributor against a rotating polyester screen with 43 micron openings. Water and some solids pass out through the rotating screen cage (200 to 400 revolutions per minute) and the thickened sludge is discharged out the bottom. The capture efficiency of each of these units is approximately 50 percent and after a single pass through the sludge is thickened by approximately 25 percent. A schematic with the various flow rates, sludge concentrations and total pounds wasted daily is shown in Figure 5. Because the clay silt particles in the waste sludge blind the screens, a thicker final sludge could be obtained if this material were eliminated.

Sludge Disposal---Raw tomato solids are trucked away to nearby ranches for cattle feed. Sludge from the peeling operation is combined with the waste activated sludge and approximately 20 loads per day (3,000 gallons per load) are hauled away by tanker for land spreading at the disposal site. After spreading, the sludge is allowed to dewater for 24 hours before being disced into the soil.

Cooling Water Treatment---Cannery cooling water is treated in a single cooling tower and discharged along with the wastewater treatment process effluent to the San Joaquin River through a common outfall. The Central Valley Regional Water Quality Control Board has tentatively set 50 milligrams per liter as the maximum COD increment concentration over background to be allowed in cooling water discharge. This value is subject to change after more data are gathered during the 1975 operating season.

Treatment Costs

The purpose of this section is to (1) briefly summarize the capital expenditures involved in the construction of the Hickmott waste treatment facility, (2) identify the daily operation costs, and (3) put these costs into perspective with respect to production costs.

Capital Costs---Capital expenditures for the Hickmott Foods wastewater treatment facility are reported in Table 11. As shown, the total cost of the plant at $885,000 (ENRCC Index = 2,240) is about one-half that of a comparable conventional secondary treatment plant design. The use of earthen basins, for both aeration and sedimentation are most significant

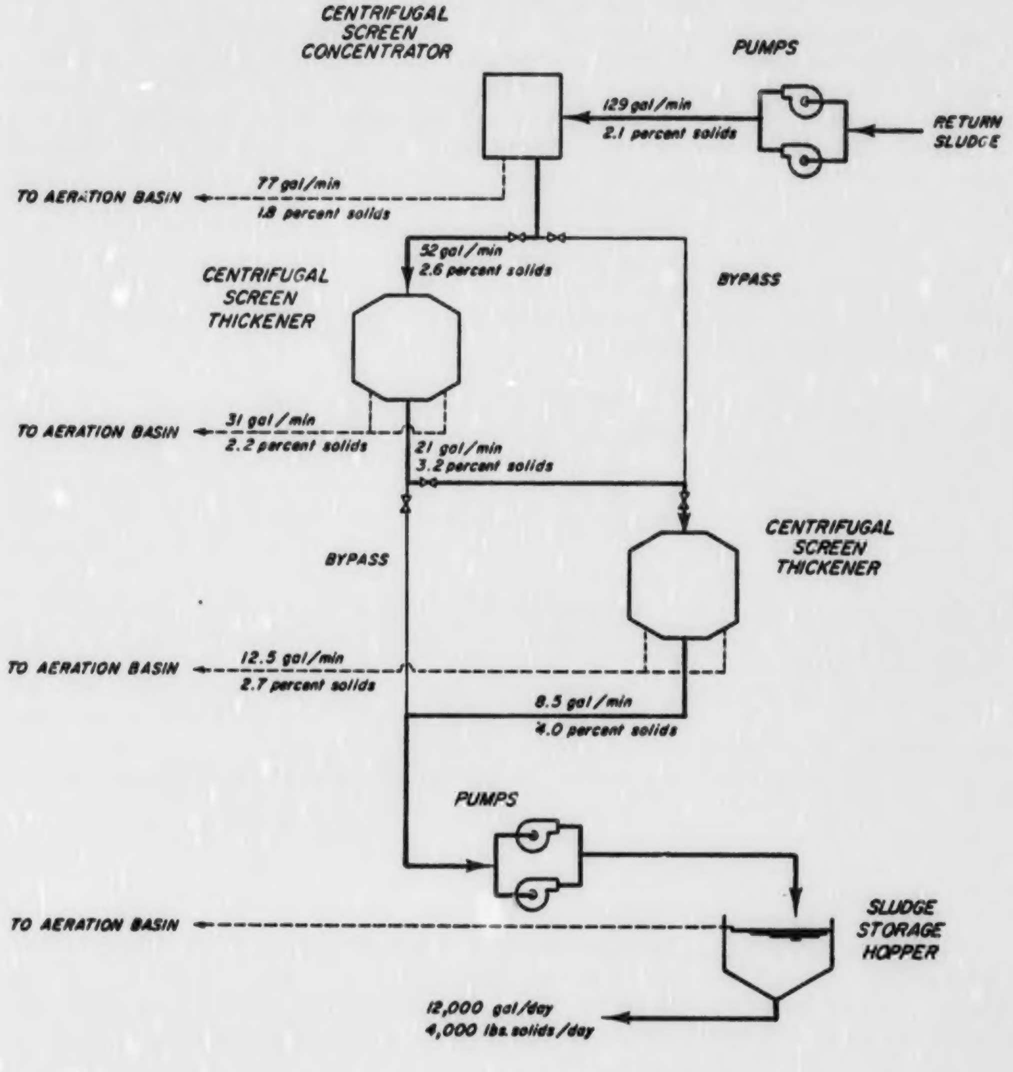

CENTRIFUGAL SCREEN CONCENTRATOR
PUMPS
129 gal/min
2.1 percent solids
RETURN SLUDGE
TO AERATION BASIN
77 gal/min
1.8 percent solids
52 gal/min
2.6 percent solids
BYPASS
CENTRIFUGAL SCREEN THICKENER
TO AERATION BASIN
31 gal/min
2.2 percent solids
21 gal/min
3.2 percent solids
BYPASS
CENTRIFUGAL SCREEN THICKENER
TO AERATION BASIN
12.5 gal/min
2.7 percent solids
8.5 gal/min
4.0 percent solids
PUMPS
TO AERATION BASIN
SLUDGE STORAGE HOPPER
12,000 gal/day
4,000 lbs. solids/day

Figure 5. Flowsheet for waste sludge thickening facilities.

Table 11. SUMMARY OF CAPITAL COSTS OF WASTEWATER TREATMENT FACILITIES[a]

Item	Cost, dollars
Major equipment	
Aerators	$ 36,000
Clarifier mechanisms	76,000
Sludge thickeners	45,000
Other equipment	101,000
Soil excavation, filling, grading, paving, etc.	70,000
Concrete work	200,000
Structural steel and supports	47,000
Pond liners	21,000
Piping, fittings and installation	95,000
Crane and rigging	5,000
Fencing and landscaping	7,000
Electrical sub-station, hook-ups, equipment and installation	74,000
Permits, impact report and other governmental fees	1,500
SUBTOTAL	$778,500
Plant labor	58,500
Design, civil, soil, marine engineering and general contracting expenses, etc.	49,000
TOTAL	$885,500

[a] Engineering News Record Construction Cost Index for San Francisco Bay Region = 2,240 (January 1974).

in terms of cost savings. Use of traveling bridge sludge pick-up mechanisms in a lined earthen basin makes possible an efficient and flexible sedimentation operation at a considerable cost savings over conventional designs employing concrete or steel tanks. Hickmott Foods was also able to reduce construction costs by doing the majority of the general contracting and labor with cannery personnel.

Operational Costs---Operational costs for wastewater treatment are associated with (1) the operation and maintenance of the wastewater treatment facilities, and (2) the hauling and disposal of sludge. Daily costs for the 1974 tomato canning season are summarized in Tables 12 and 13. In reviewing Tables 12 and 13, it can be seen that one-half of the daily operating expenses are associated with the disposal of the waste solids and sludge.

Annual Cost---An estimate of the total daily cost to Hickmott Foods including the construction and operational costs is given in Table 14. For the 1974 tomato canning season, the cost of treatment amounted to 13.0 cents per case of tomato product. On a per can basis, the cost of wastewater treatment at Hickmott Foods is approximately 0.5 cents.

FUTURE IMPROVEMENTS AND WASTE REDUCTIONS

With the measures Hickmott Foods has instituted to reduce and treat the wastes generated from canning operations, the company is now in compliance with state and federal discharge requirements. Nevertheless, additional steps are being taken or considered to reduce waste loads and treatment and/or disposal costs. These developments are outlined below.

Reduction in Water Usage

Because Hickmott Foods has abandoned its sweet potato and asparagus operations, daily water usage will be reduced further by shortening the lengths of belts on which peeled tomato products must travel. This change will eliminate about 50 gallons per minute of water now used for belt lubrication. In turn, this will reduce the peak water usage in the cannery to about 750 to 800 gallons per minute. This quantity is considered to be the minimum water usage possible to maintain sanitary conditions. Heightened concern by the US Department of Agriculture over the issue of machine mold may ultimately result in increased per ton water usage by Hickmott Foods.

Table 12. SUMMARY OF DAILY OPERATING COSTS FOR WASTEWATER TREATMENT FACILITIES DURING 1974 CANNING SEASON

Item	Cost, dollars/day
Power (520 hp x 24 hr x 0.746 kw/hp x 0.02 kwh)	$186
Chemicals (acid, ammonia and phosphate)	130
Supplies	50
Testing and monitoring operations (24 hr/day @ $5.50/hr)	132
Mechanic-operator (10 hr/day @ $8.00/hr)	80
TOTAL	$628

Table 13. SUMMARY OF DAILY SOLIDS AND SLUDGE DISPOSAL COSTS DURING 1974 CANNING SEASON

Item	Cost, dollars/day
Truck driver (1 x 24 hr/day x $7.50/hr)	$180
Truck operation (solids) (4 trips/day x 14 miles/trip x $0.30/mile)	17
Truck operation (sludge) (20 trips/day x 20 miles/trip x $0.35/mile)	140
Solids disposal fees (4 loads/day x $3.60/load)	14
Sludge disposal fees	67
Discing tractor and operator (1 x 16 hr/day x $13/hr)	208
TOTAL	$626

Table 14. SUMMARY OF TOTAL DAILY COST FOR WASTEWATER TREATMENT DURING 1974 TOMATO CANNING SEASON[a]

Item	Cost
Capital cost, dollars/day (\$885,500[b] x 1,627[c]/90 day/yr)	\$1,601
Treatment plant operation,[d] dollars/day	628
Solids and sludge disposal,[d] dollars/day	626
TOTAL, dollars/canning day	\$2,855
Cost/case,[e] cents/case	13.0
Cost/can, cents/can	0.5
Cost/ton of raw tomatoes, dollars/ton[f]	\$4.28

[a] Based on a 90-day canning season.

[b] Capital cost from Table 5.

[c] Capital recovery factor = 0.1625 (10 yrs @ 10%).

[d] Cost data from Table 6.

[e] Based on two million cases of number 2½ cans.

[f] Based on 60,000 tons.

Flow Equalization

In activated sludge systems such as the one employed at Hickmott Foods, hydraulic surges cause large amounts of mixed liquor solids to be transferred from the aeration basin to the sedimentation basin in a short amount of time. If these surges are sustained and are of large enough magnitude, a deterioration in effluent quality can result as the sludge blanket builds up. With the high aerations solids employed at Hickmott Foods, increasing the sludge return rate does not effectively draw down the sludge blanket because of the very low settling velocity of the mixed liquor at a concentration of 10,000 milligrams per liter TSS. To reduce the impact of the flow surges, the top 18 to 24 inches of the aeration basin is to be used for flow equalization. A floating weir will be used to maintain a constant flow to the sedimentation basin regardless of the water level in the aeration basin.

Solids Disposal

Currently, all solid and sludge wastes must be hauled away for disposal. As long as nearby disposal sites are available, this method is cost effective. If, however, the present system proves to be unworkable, then further sludge dewatering must be considered. Because a large amount of concentrated carbonaceous waste is produced, the use of a pyrolysis process to produce activated carbon is now being evaluated by personnel from the Jet Propulsion Laboratory of the California Institute of Technology. The production of a useful by-product that can be sold to nearby industries would reduce otherwise prohibitively high operating cost for this method of sludge processing.

Peel Waste Recovery

At present, about 120 tons per day of tomato constituents are lost as caustic peeling sludge. Dow Chemical Company, in cooperation with USDA-WRRC and NCA conducted a test run on September 26, 1974 at Hickmott Foods to investigate the feasibility of recovering the tomato peeling sludge after acidification as products. The flow scheme incorporated in these tests is shown in Figure 6. The quality of the puree made from a 1:1 blend of acidified caustic peeling sludge and fresh crushed tomatoes was judged to be good with respect to both flavor and appearance by NCA. The quantities of acid required to lower the pH value of the caustic juice was kept to a minimum by operating the peelers at 8 percent caustic. Further studies are being conducted by USDA, Dow, NCA and EPA to establish whether the method can become accepted cannery practice. The main areas of concern include (1) pesticide residuals, (2) wetting agent carryover, and (3) chemical by-product formation. If this peel

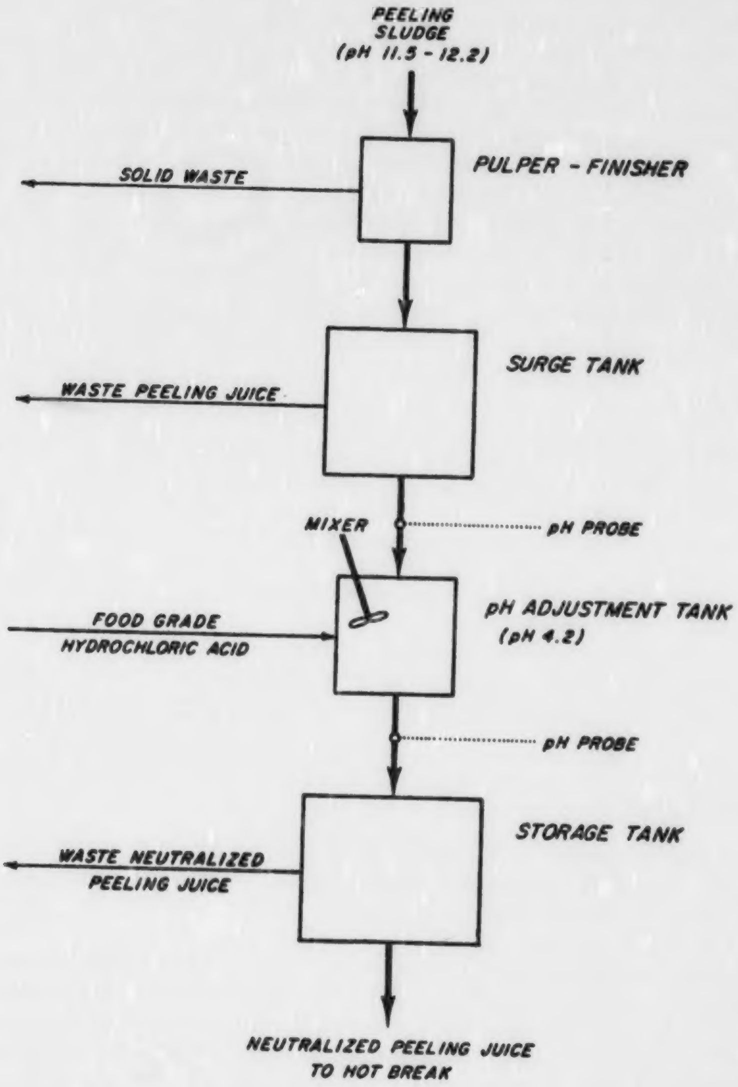

PEELING SLUDGE (pH 11.5 - 12.2)
PULPER - FINISHER
SOLID WASTE
SURGE TANK
WASTE PEELING JUICE
MIXER
pH PROBE
pH ADJUSTMENT TANK (pH 4.2)
FOOD GRADE HYDROCHLORIC ACID
pH PROBE
STORAGE TANK
WASTE NEUTRALIZED PEELING JUICE
NEUTRALIZED PEELING JUICE TO HOT BREAK

Figure 6. Flowsheet for proposed recovery of waste peeling sludge.

recovery scheme can be proven to be safe, Hickmott Foods will be able to recover an additional 4 tons per hour of usable tomato material, reduce its waste loss from 16 to 6 percent, and cut the number of gallons of sludge that must be hauled for disposal by one-half.

Raw Product Transportation

Hickmott Foods has also contemplated the installation of bulk tub dumping facilities (boxes are now used). However, based on preliminary studies it was found that when ripe peeling tomatoes are stacked 30 to 36 inches high, the bottom one-quarter by weight are broken or cracked. In a plant such as Hickmott where over 50 percent of all the tomatoes are peeled, this amount of damaged product and extra waste cannot be tolerated.

ACKNOWLEDGEMENTS

The authors thank the owners and management of Hickmott Foods, Inc., for their conern for the environment and their willingness to try alternative methods and equipment for wastewater management.

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PILOT-SCALE TREATMENT OF BRINED CHERRY WASTEWATERS

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M. R. Soderquist*
D. W. Taylor*
E. Gerding**
J. Ostrin***

INTRODUCTION

In the manufacture of maraschino and glacé cherries, the fruit is first leached in a sulfur dioxide-calcium chloride-water brine. From there, the fruit is processed. Unit operations include stemming, sizing, pitting and packing. The process is diagrammed in Figure 1. The wastewaters are characterized by low pH's and high levels of biological oxygen demand (BOD) and sulfur dioxide.

This paper describes a two-phased investigation of the treatability of these wastewaters by aerobic biological processes. The first phase consisted of a bench-scale study at Aqua Tech Laboratories, Inc., in Portland, Oregon in May 1974. In this study, the feasibility of the oxidation of free and combined sulfur dioxide to sulfate under aerobic conditions was demonstrated. In the second phase, a 7,000 gallon pilot plant was erected on-site at The Dalles Cherry Growers, Inc., at The Dalles, Oregon. The system was operated in an aerated lagoon mode for four months, then in an extended aeration mode with complete sludge recycle for three weeks.

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**The Dalles Cherry Growers, Inc., The Dalles, Oregon.
***Stadelman Fruit, Inc., The Dalles, Oregon.

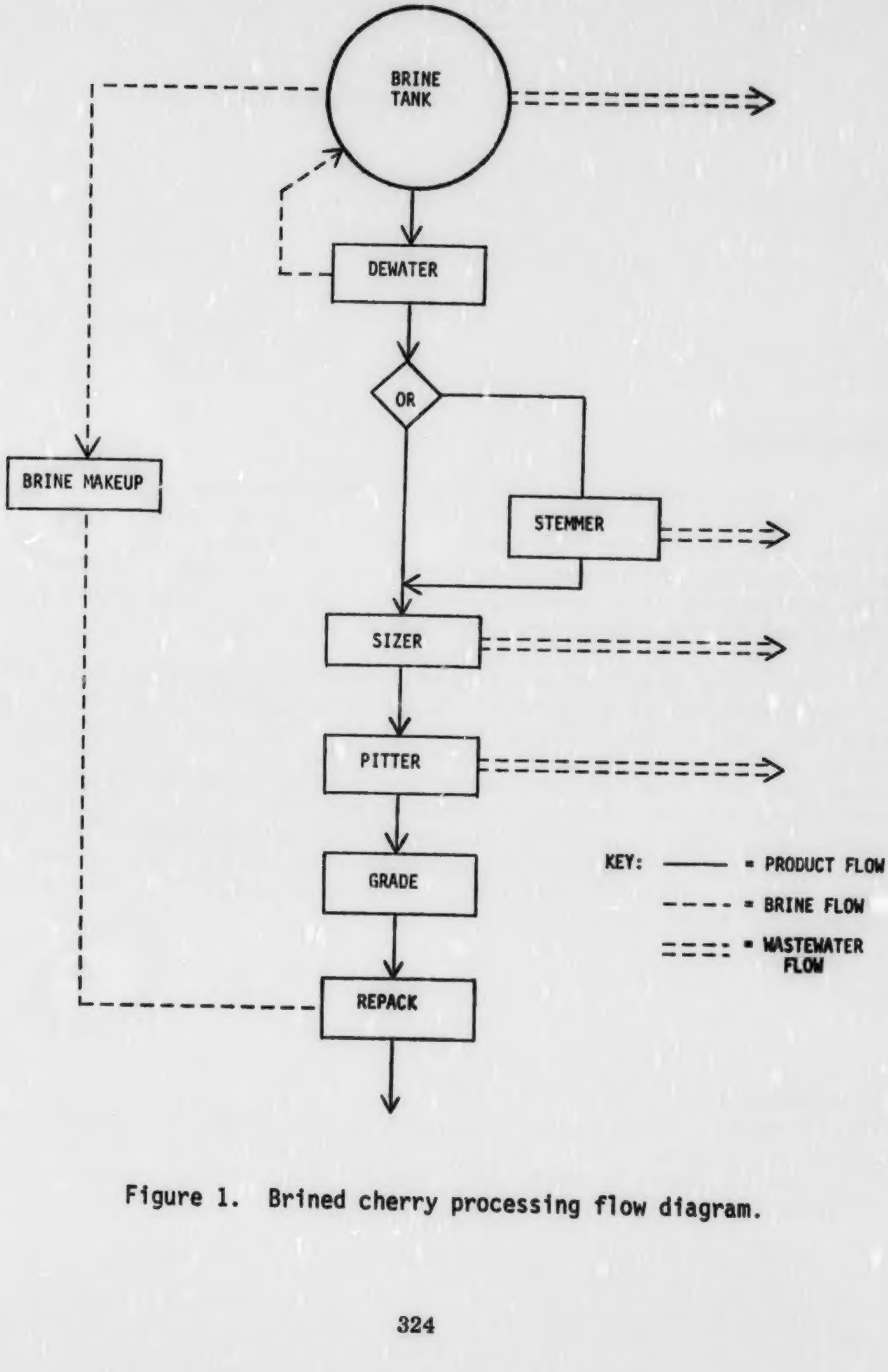
BRINE TANK
DEWATER
OR
BRINE MAKEUP
STEMMER
SIZER
PITTER
GRADE
REPACK
KEY:
= PRODUCT FLOW
= BRINE FLOW
= WASTEWATER FLOW

Figure 1. Brined cherry processing flow diagram.

METHODS AND RESULTS

Bench Scale SO_2 Conversion Study

Although in the brined cherry industry efforts are made to conserve brine, a certain amount does enter the plant waste stream, resulting in sulfur dioxide (SO_2) concentrations typically in the range of 200 to 300 milligrams per liter. In response to conern over the chemical and environmental effects of the SO_2, the previously-mentioned bench scale study was performed.

Two Plexiglass units of approximately 4 liters each were charged with a 1:25 dilution and a third unit with a 1:30 dilution of concentrated spent cherry brine. All units were seeded with raw sewage. Two units (one each at 1:25 and 1:30) were aerated with the pH initially adjusted to 6.1, and the third was aerated at an initial pH of 4.6, which is typical of the combined wastes emanating from the processing plant. After six hours, the pH in the first two units was further adjusted to 6.6. All of the units were then allowed to seek their own pH level. The units were monitored for pH and for concentrations of free and combined sulfur dioxide (SO_2, HSO_3^- and $SO_3^=$) and sulfate ($SO_4^=$).

The results of the study are depicted graphically in Figures 2 and 3. On Figure 2 appear the results using dilutions of 1:25 and 1:30 with pH adjustment. On Figure 3 appear the results of the test on the third unit, with a 1:25 dilution and no pH adjustment.

As can be seen from Figure 2, the conversion of $SO_3^=$ and HSO_3^- to $SO_4^=$ was essentially complete after five days of aeration when the pH was adjusted initially. Without the benefit of pH adjustment, this conversion still took only six days, as shown in Figure 3.

The following presents the results of a sulfur mass balance on the system in Unit A (1:25 dilution):

Initial sulfate in brine = 12 mg/l as SO_4
Initial total sulfur dioxide = 240 mg/l as SO_4
Total sulfur in untreated brine = 252 mg/l as SO_4

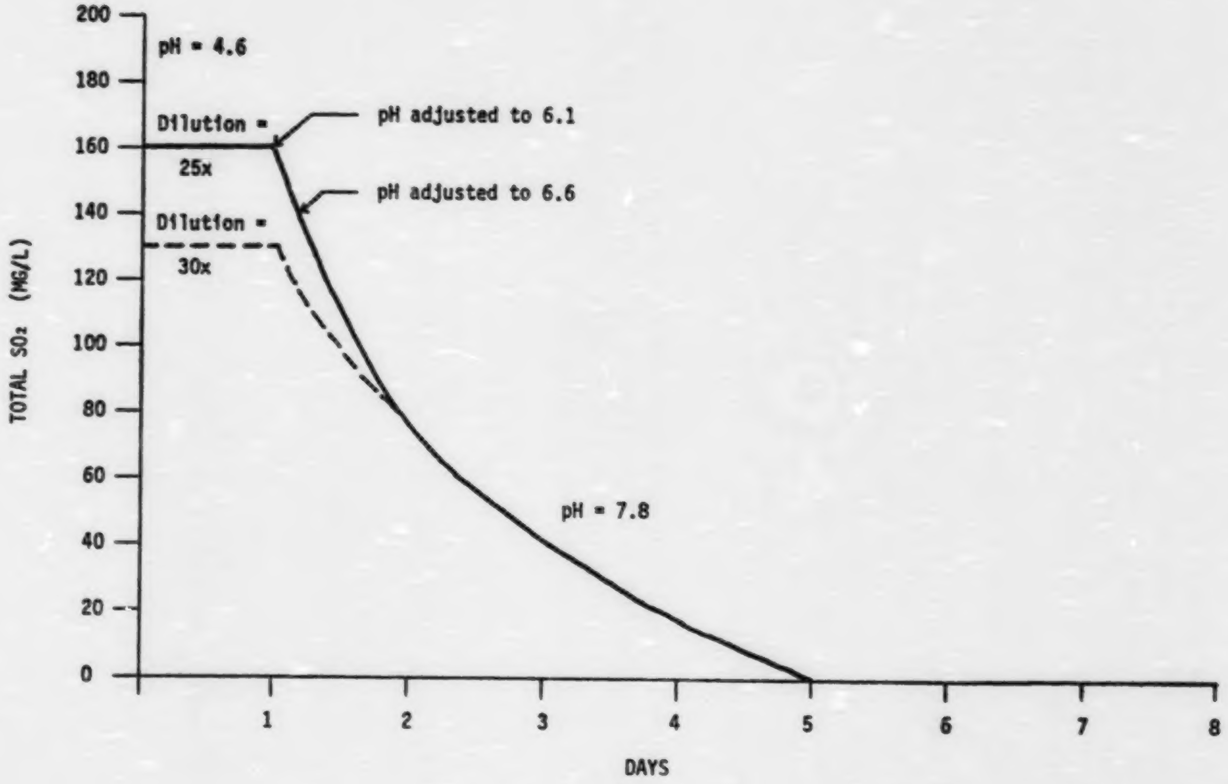

Figure 2. Aeration with pH adjustment.
(25x and 30x dilution; seeded cultures)

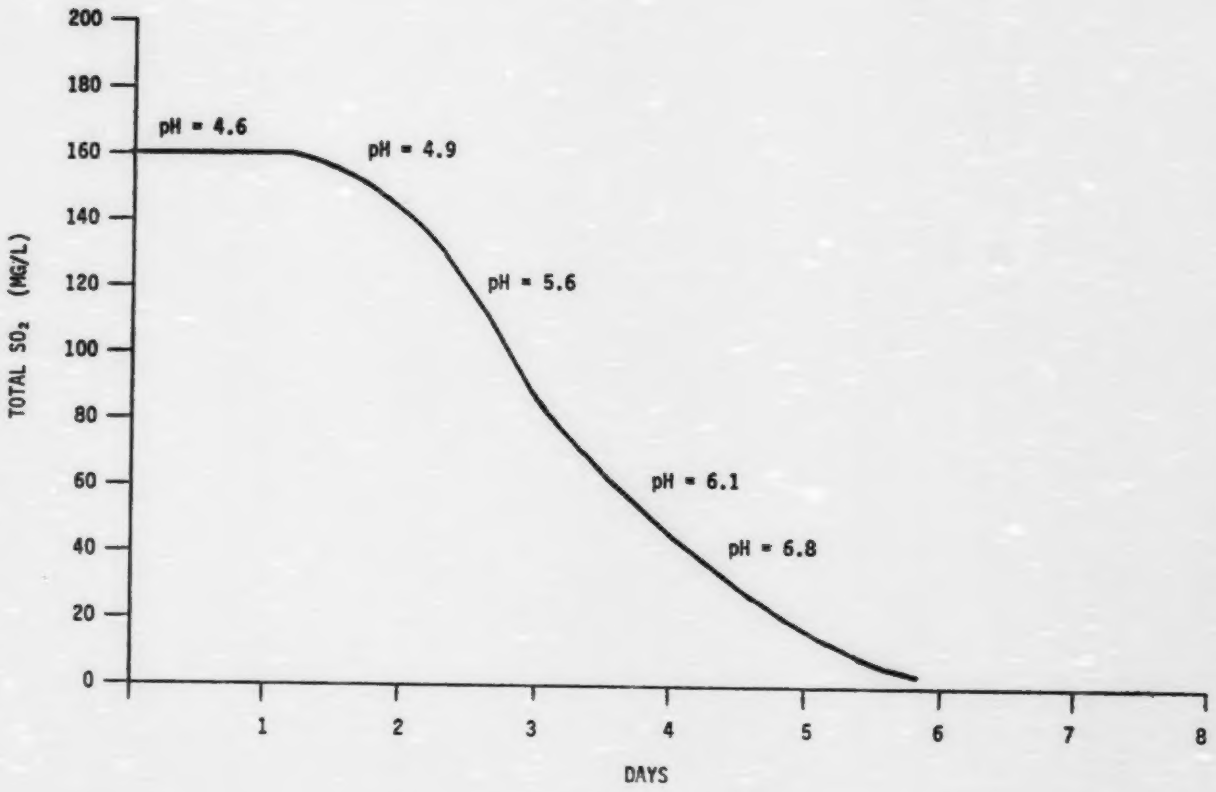

Figure 3. Aeration without pH adjustment.
(25 x dilution; seeded culture)

After five days of aeration:

Sulfate in mixed liquor = 250 mg/l as SO_4
Total sulfur dioxide in mixed liquor = 0 mg/l as SO_4
Total sulfur in mixed liquor = 250 mg/l as SO_4

This indicates that virtually all total free and combined sulfur dioxide was converted to sulfate during the aeration process. It is significant to note that very little SO_2 was released to the atmosphere during that process. This finding is consistent with the known relationship between free and combined sulfur dioxide as discussed by Payne *et al.*,[1] wherein it is indicated that virtually no free gaseous SO_2 exists in solution above a pH of 4.4 and that loss of excessive amounts of SO_2 to the atmosphere does not occur above a pH of 2.5. Since the stripping action of the air would be a function of the availability of free SO_2, the above results are realistic.

Pilot Plant Study

Satisfied with the results of the bench-top study, the investigators began an on-site pilot-plant study at The Dalles Cherry Growers, Inc., plant. Figure 4 shows the basin equipment and piping layout for the pilot plant. The raw wastewater was pumped from an underground sewer to a distribution box that delivered a predetermined constant flow to the aeration tank and returned the excess flow to the sewer through an overflow pipe. The 7,000 gallon aeration tank contained a one-horsepower floating aerator to provide oxygen and completely mix the tank contents. The aeration tank liquid (mixed liquor) was transferred by gravity to a 2 foot by 2 foot by 4 foot deep settling tank. Not shown in Figure 4 is the sludge recycle pump and piping used in the study during the extended aeration mode.

Operation, Sampling and Testing Procedures

The pilot plant study was performed in three series. A description of these series and the procedures followed for operation, sampling and testing follow:

Series I---July 11 to July 25. During this period, the plant was processing only fresh cherries; consequently, no brine was contained in the wastewaters. The pilot plant was operated in an aerated lagoon mode (no sludge recycle) at a 5-day retention time.

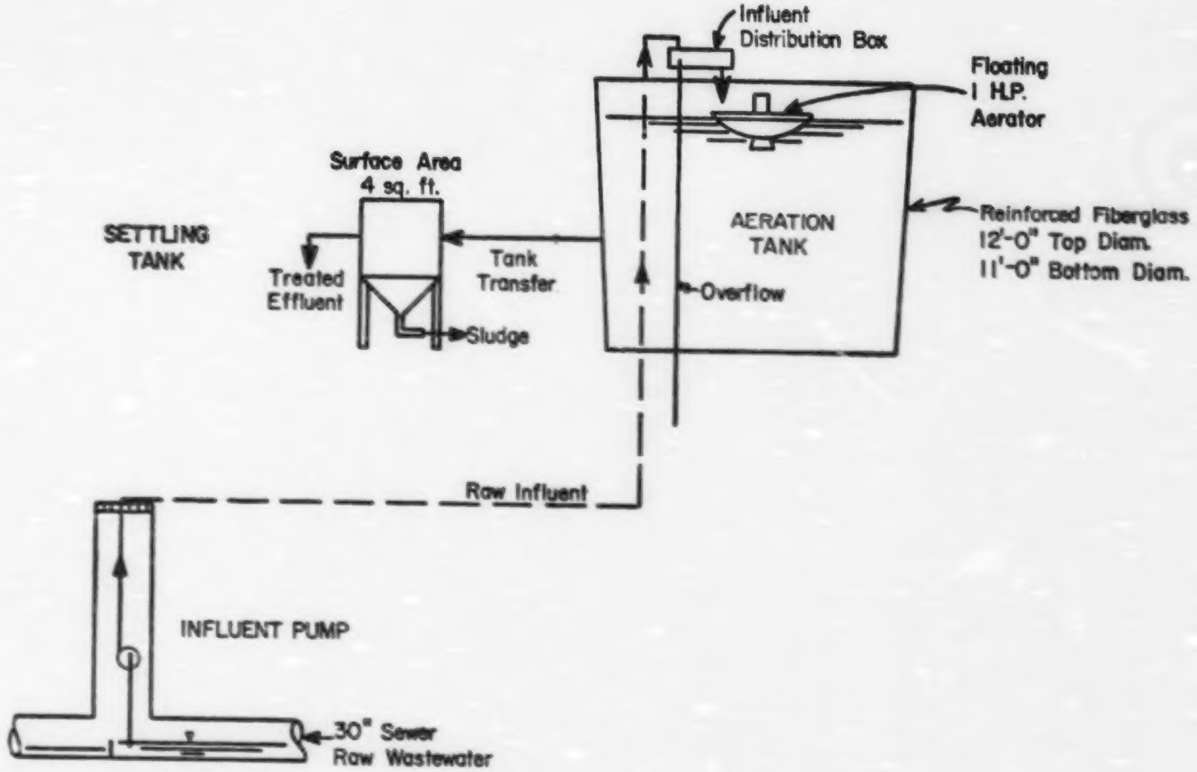
Influent
Distribution Box
Floating
1 H.P.
Aerator
Surface Area
4 sq. ft.
SETTLING
TANK
Treated
Effluent
Tank
Transfer
Sludge
AERATION
TANK
Overflow
Reinforced Fiberglass
12'-0" Top Diam.
11'-0" Bottom Diam.
Raw Influent
INFLUENT PUMP
30" Sewer
Raw Wastewater

Figure 4. Pilot plant diagram.

To start the biological system efficiently, the aeration tank was seeded with activated sludge from The Dalles wastewater treatment plant. After dilution the mixed liquor suspended solids level was approximately 2,000 milligrams per liter.

The wastewater influent flow rate was set at 1.0 gallons per minute and operated for 24 hours per day, corresponding to the processing plant operation (including a 6-hour cleanup shift). The wastewaters were assumed to be nutrient deficient, so nutrients were added in the form of urea (46 percent N) and ordinary garden fertilizer (6 percent N, 10 percent P_2O_5, 10 percent $SO_4^=$) at a BOD:N:P ratio of 100:5:1.

Samples of the pilot plant influent and effluent were collected daily. Some samples were analyzed in the Cherry Growers' laboratory with check samples sent to Aqua Tech. All analyses were performed according to Standard Methods.[2]

Because of the very short length of operating time before the end of the processing season, only preliminary evaluations of treatability parameters such as reaction rates and settleability were conducted in this series.

Series II---September 15 to November 15. The plant was processing only brined cherries at this time. The pilot plant was operated in an aerated lagoon mode with three detention times, ranging from 4.8 to 18 days. Wastewater was pumped to the pilot plant on a 12-hour per day, 5 days per week basis, matching the processing plant's operation. Reseeding of the aeration tank was unnecessary because of the biomass still present from Series I, even though the system had been aerated for over seven weeks without the addition of any substrate. A viable mixed liquor was present within a few days. Nutrients were added in the form of urea and tri-sodium phosphate in the same ratio as in Series I.

Daily samples of the influent were taken using an automatic composite sampler on a ten minute cycle. In addition, daily grab samples of the mixed liquor and effluent were taken. The schedule of analyses is shown in Table 1.

Series III---November 18 to December 12. In this series, operation of the system in an extended aeration mode was evaluated. All sludge from the underflow of the settling unit was recycled to the aeration tank. The system was operated at a hydraulic retention time of 4.8 days. All other operation and testing procedures were identical to those in Series II.

In addition to the analyses outlined in Table 1, occasional checks were made on the influent and effluent concentrations of sulfate, total

Table 1. SCHEDULE OF ANALYSES FOR SERIES II AND III

Test	Sample station[a]		
	Influent	Mixed liquor	Effluent
BOD, unfiltered	D	-	D
BOD, filtered	W	D	W
COD, unfiltered	D	-	D
COD, filtered	W	D	W
Suspended solids	W	D	D
Volatile suspended solids	W	D	D
pH	D	D	D
Sludge volume index	-	D	-
Sulfur dioxide	D	-	D

[a] D = Daily
W = Weekly

phosphorus and total Kjeldahl nitrogen, and on the mixed liquor temperature. As in Series I, most of the tests were done in the Cherry Grower's laboratory, with samples occasionally being sent to Aqua Tech to provide checks on accuracy and to perform the more complex analyses.

Steady-state conditions were judged to have occurred when the mixed liquor suspended solids level remained relatively constant for several days. In addition to evaluation of steady-state conditions, the resistance of the system to shock loadings was investigated. These loadings included surges of organics, flow and chlorite wastewater from the secondary bleaching process.

Results of Pilot-Plant Study

Table 2 lists the results of Series I through III at steady-state conditions. The data shown that BOD removals in excess of 98 percent were achieved in all of the series. Oxidation of sulfur dioxide in Series II and III was virtually complete in all of the trials and the system contained enough natural buffering capacity to consistently provide an effluent pH near 7.0 without chemical neutralization of the wastewaters.

The data confirm the assumption that the waste is deficient in nitrogen and phosphorus, with a BOD:N:P of approximately 100:1.4:0.3, compared to a ratio of 100:5:1 considered adequate for good biological growth.[3]

Figure 5 shows the effect of hydraulic retention time on the sludge volume index (SVI) for the aerated lagoon system. The SVI had a value of 190 at 9.7 days retention time and over 500 for the other trials. A value of 860 was recorded in Series I. As shown in Table 2, the food:microorganism ratio (F:M) varied from 0.21 at 18 days retention time to 0.45 at 4.5 days. The best settling sludge developed at a retention time of 9.7 days, at which the F:M ratio had a value of 0.31. This observation is consistent with the statement in Metcalf and Eddy[4] that good settling characteristics result from mean cell residence times of 6 to 15 days (for the aerated lagoon mode, the mean cell residence time is equivalent to the hydraulic retention time).

The high values of SVI were observed to be a result of filamentous bulking, as discussed by Pipes.[5] Microscopic examination of the mixed liquor revealed the presence of significant numbers of filamentous organisms. Their development may have been linked to the fact that the wastewater had a high concentration of soluble carbohydrate materials, an environment in which filamentous organisms have an advantage. In some cases, bulking has been seen to result from conditions such as low

Table 2. PILOT PLANT PERFORMANCE DATA[a]

Hydraulic retention time, days	Series I[b]		Series II[b]						Series III[c]	
	4.5		4.8		9.7		18.0		4.8	
	I	E[d]	I	E[d]	I	E	I	E[d]	I	E[d]
BOD_5, mg/l	1,510	8	2,910	40	2,575	41	2,500	31	1,870	19
COD, mg/l	2,880	94	5,200	200	3,860	230	3,700	110	2,800	100
Suspended solids, mg/l	120	70	140	40	130	110	130	29	110	-
TKN, as N, mg/l	16	8	51	12.4	39	12.3	-	-	-	-
PO_4, as P, mg/l	3.8	2.6	9.9	3.9	10.0	7.9	-	-	-	-
pH	-	-	4.7	7.1	5.4	7.0	4.9	7.2	5.2	7.0
Sulfur dioxide, mg/l	-	-	350	Trace	Trace	Trace	240	Trace	Trace	Trace
Sludge volume index, ml/gm	860		540		190		510		800	
Food:microorganism	0.45		0.38		0.31		0.21		0.43	
Temperature, °C	19		13		17		8		6	

[a] I = Influent; E = Effluent

[b] Aerated lagoon system.

[c] Extended aeration.

[d] Supernatant of mixed liquor settled artificially in laboratory.

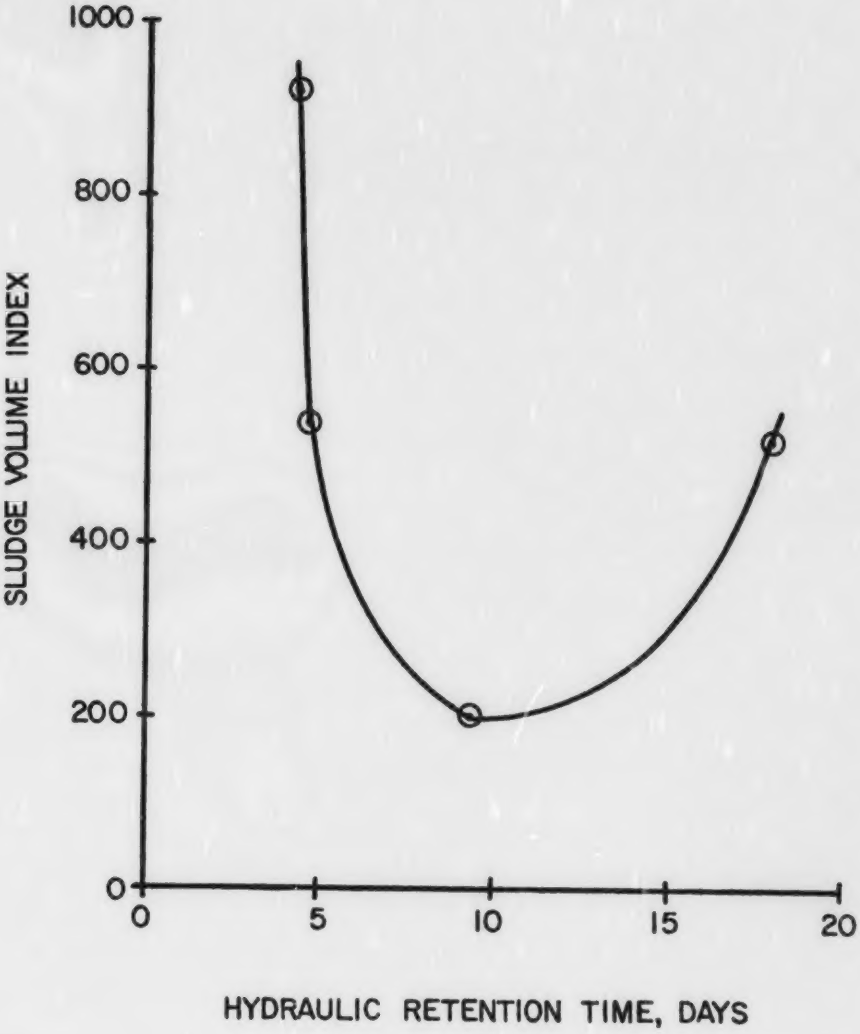

Figure 5. Sludge volume index versus retention time for aerated lagoon system.

dissolved oxygen levels in the aeration tank, adverse pH or insufficient levels of nutrients.[5] None of these conditions were believed to exist in the pilot plant, however.

In Series III, an attempt was made to control the loading rate by recycling sludge back to the aeration tank in an extended aeration mode. The object was to increase mixed liquor concentration, thereby adjusting the F:M ratio to obtain a level at which good settling would occur. The system was operated at a retention time of 4.8 days.

The results obtained were not encouraging. The SVI was observed to be about 800. At this level, it was not possible to achieve separation or concentration of the sludge in the settling unit. Considerable sludge was lost in the effluent, rather than being recycled. One sample collected from the settling tank overflow had a suspended solids concentration of 1,850 milligrams per liter with corresponding BOD of over 1,000 milligrams per liter. The conclusion of the processing season precluded further attempts to control the process.

Evaluation of Shock Loadings

In addition to the evaluations already discussed, the resistance of the aerated lagoon system to shock loadings was investigated. These loadings included organics, flow and chlorite wastewater from the secondary bleaching process.

An organic shock load occurred on October 17 when plant operational problems resulted in the spillage of a large amount of concentrated brine from the pitting process. The pilot plant was operating at a 4.8 day retention time. The spill caused the influent BOD composite to increase to approximately 1.5 times its normal level resulting in an F:M ratio of 0.70. This caused the sludge volume index to increase from 270 to over 600. Such a response is not uncommon in biological treatment systems, especially when the wastewater is high in soluble BOD.[5]

To simulate a hydraulic overload, the influent pumping rate was increased to four times the normal flow while the strength of the wastewater was unchanged. The systems response was favorable. That is, efficient treatment was maintained along with a beneficial effect on the SVI.

Of particular interest was the response of the system to the chlorite wastes from the secondary bleaching tank. During secondary bleaching, cherries still containing blemishes after the initial brining step are held in a solution that is approximately 0.75 percent sodium chlorite. Depending upon conditions in the tank, bleaching ranges from several days to weeks and results in a blemish-free product. When bleaching is complete, the solution is leached from the cherries with a continuous stream of fresh water. Since sodium chlorite is a powerful oxidant, concern existed regarding the toxic effects this waste might have on the treatment system. A 7,000 gallon tank containing the chlorite solution was leached on November 11. The pilot plant influent was observed to immediately change from its usual pale yellow to a bright yellow-green color. Analysis of grab samples revealed that the primary shock loading occurred within the first two and one-half hours. The chlorite concentration peaked at 170 milligrams per liter after 30 minutes. The pH of the wastewater was down about one unit from its normal value of 5.0.

The introduction of chlorites appeared to have little effect on the performance of the biomass in the aeration tank. Efficient treatment was maintained during and after the chlorite loading. An immediate reaction was a reduction in the SVI from 530 on the 10th to 255 on the 13th. The use of an oxidizing agent, such as chlorine, in controlling bulking sludge has been well documented, and it appears that the bleaching waters may actually be of benefit to the treatment system.

DETERMINATION OF KINETIC COEFFICIENTS

Substrate Removal

A mathematical model commonly used to describe the treatment efficiencies in an aerated lagoon system is that which assumes first-order kinetics[4]:

$$S_e = \frac{S_o}{1 + Kt} \qquad (1)$$

where S_e = effluent substrate concentration, mg/l

S_o = influent substrate concentration, mg/l

K = first-order substrate removal rate, day^{-1}

t = hydraulic retention time, days

K, the removal rate, has been noted to depend on temperature as given by the expression[4]:

$$K_T = K_{20} \times \Theta^{(T - 20)} \quad (2)$$

where K_T = reaction rate at T degrees C, days^{-1}

K_{20} = reaction rate at 20 degrees C, days^{-1}
Θ = temperature activity coefficient
T = temperature, degrees C

Values of K_T computed from Table 2 are plotted against temperature in Figures 6 and 7, based on BOD and COD, respectively.

From Figure 6, the following formulation based on BOD, is derived:

$$K_{BOD_T} = 14.5 \times 1.085^{(T - 20)} \quad (3)$$

From Figure 7, using COD values, equation 4 is obtained:

$$K_{COD_T} = 4.61 \times 1.07^{(T - 20)} \quad (4)$$

Sludge Growth

An empirical formula defining the relationship between sludge growth and substrate utilization is[4]:

$$\frac{dx}{dt} = Y \frac{ds}{dt} - bX \quad (5)$$

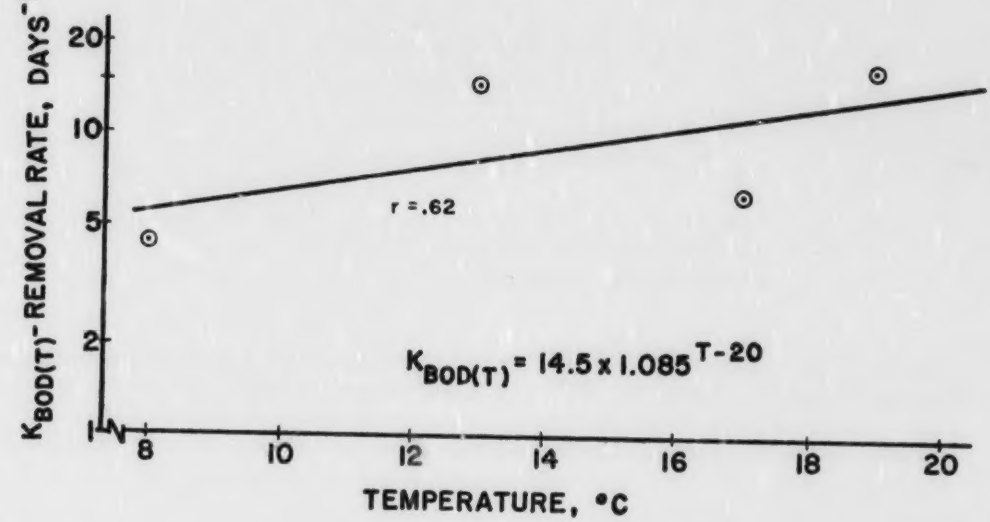

Figure 6. BOD removal coefficient versus temperature.

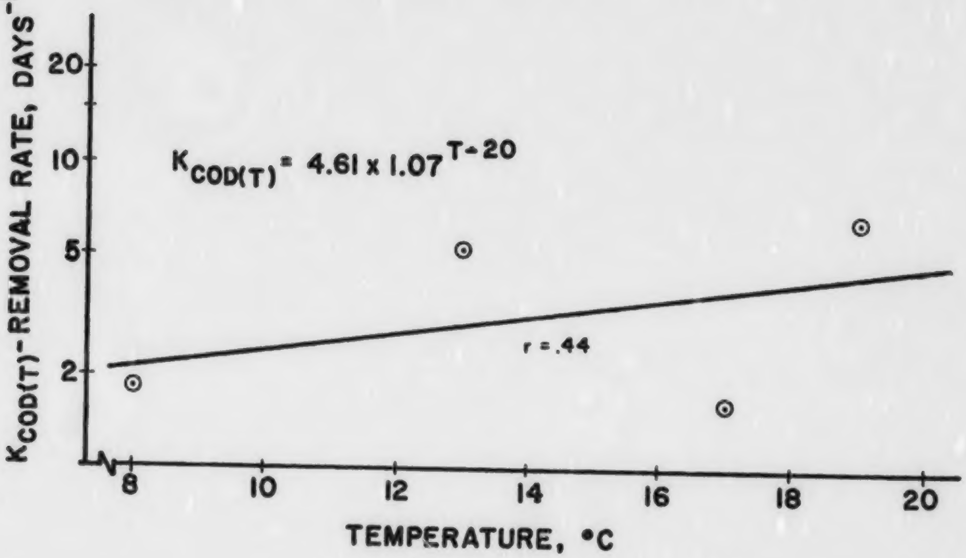

Figure 7. COD removal coefficient versus temperature.

where $\frac{dx}{dt}$ = net growth rate of organisms, mass/volume-time

Y = growth-yield coefficient, mass cells/mass substrate utilized

$\frac{ds}{dt}$ = rate of substrate utlization by organisms, mass/volume-time

b = decay coefficient, time^{-1}

X = concentration of microorganisms

Rearranging, the following is obtained:

$$\frac{\Delta S/\Delta T}{X} = Y \frac{\Delta S/\Delta T}{X} - b \tag{6}$$

The term on the left-hand side is equivalent to the inverse of the hydraulic retention time in a no-recycle system. The term $\frac{\Delta S/\Delta T}{X}$ is equivalent to the F:M ratio. These two terms are plotted against each other in Figure 8 and the values of Y and b determined from a regression line fit. These values are:

Y = 0.62 mg cells/mg BOD utilized

b = 0.06 days^{-1}

DISCUSSION

The values of the coefficients given in the above section were computed using the values of total BOD and COD as given in Table 2. Except for Series I, the system was run on a non-continuous feed basis, that is, the wastewater was supplied to the system only 12 hours per day. Effluent samples were taken after the system was aerated without feed for 12 hours. The values obtained may therefore differ from those obtained in a continuous system.

CONCLUSIONS

1. The wastewaters from the brined cherry pitting process are highly treatable in an aerobic biological treatment process.

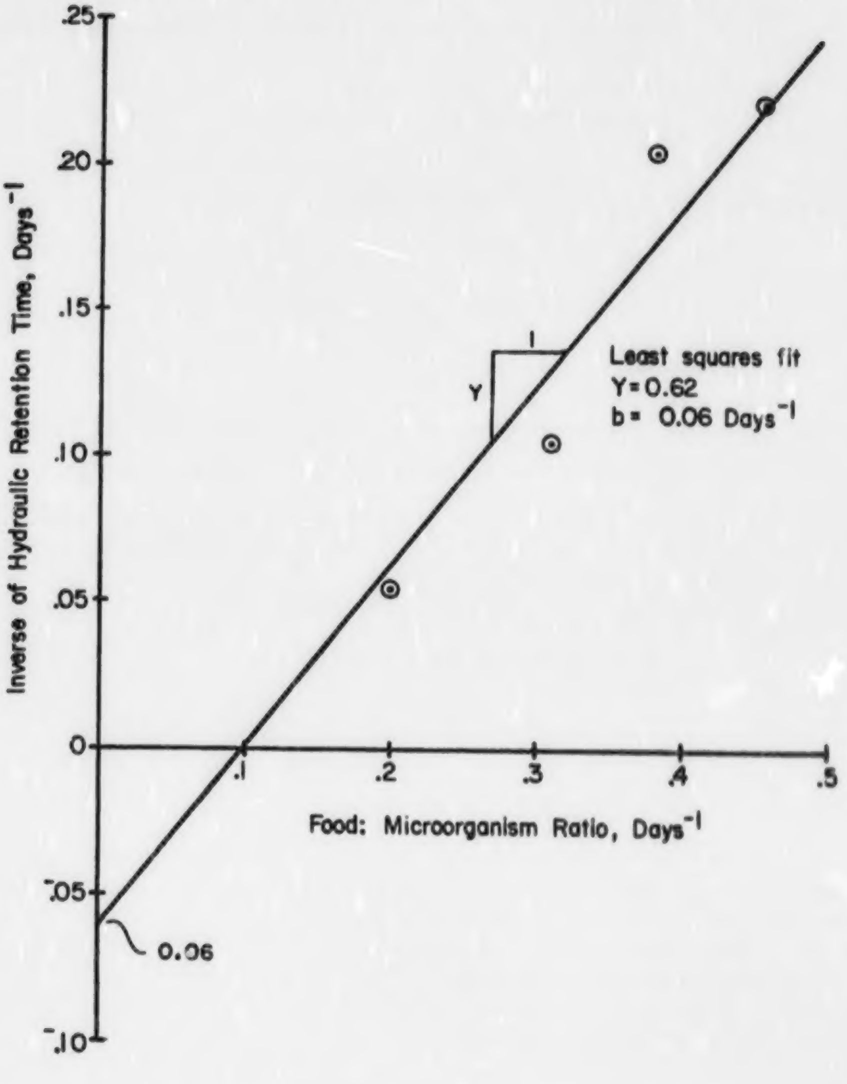

Figure 8. Determination of growth-yeild coefficient Y and decay coefficient b.

2. The system effluent will be virtually free of sulfur dioxide and have a pH near neutrality without the need for chemical treatment.

3. The most significant problem to be faced is that of operating the system so that good sludge settling characteristics are maintained.

4. The optimum retention time appears to be about ten days in an aerated lagoon mode.

5. The aerated lagoon system appears to be susceptible to upset by the introduction of organic shock loading.

6. Hydraulic and chlorite shock loadings should not cause upsets, with the latter being of possible benefit.

ACKNOWLEDGEMENTS

The authors wish to express thanks to the staffs of Stadelman Fruit, Inc., and The Dalles Cherry Growers, Inc., both of The Dalles, Oregon, for their cooperation throughout the study and for their willingness to release the data contained in this report. Thanks are also expressed to the Pacific Northwest Environmental Research Laboratory of the US Environmental Protection Agency, Corvallis, Oregon, for their loan of equipment used in the pilot plant.

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CHARACTERIZATION AND POTENTIAL METHODS FOR REDUCING WASTEWATER FROM IN-PLANT HOG SLAUGHTERING OPERATIONS

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INTRODUCTION

The purpose of the project is to determine physically the waste loads and their characteristics generated by the subprocesses employed in a typical hog slaughtering operation. After waste stream characterizations, our intent is to make selected in-plant modifications which will achieve one or more of the following objectives:

1. Reduce water use,
2. Reduce and/or prevent product loss to sewers, and
3. Reuse wastewater.

Due to stringent US Department of Agriculture (USDA) inspection requirements, potential for reuse is greatly limited.

Until recently, almost all emphasis in handling meat industry wastewaters had been directed toward end-of-pipe treatment. However, it has been apparent to those familiar with the industry that the potential exists for achievement of significant wasteload reductions through in-plant measures.

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These in-plant measures can be designed into a new plant, but they present numerous implementation problems in existing facilities.

The enactment of the Federal Water Pollution Control Act Amendments of 1972 has provided emphasis on in-plant measures as "Best Available Technology" required to be met by July 1, 1983. Effluent guidelines and standards promulgated by the US Environmental Protection Agency (EPA) envision extensive in-plant control of pollution losses. The recently published Red Meat Industry Development Document[1] makes reference to water control systems and procedures to reduce water use by about 50 percent.

Hog slaughtering operators should be interested in the results of this present study in that approximately 50 percent of these facilities are direct dischargers to public waters, while most of the remainder are subject to the public facility user charge and industrial cost recovery provisions of the 1972 Act (Public Law 92-500).

STATUS OF THE MEAT INDUSTRY

The meat industry is generally grouped in the food product category classification. The 1973 employement data for comparison of the entire food industry and with all manufacturing is shown in Table 1.

A breakdown by species of the total federally inspected slaughter in 1974 is shown in Table 2.

Table 3 shows the 1974 slaughter as related specifically to hogs.

Oscar Mayer and Company, Inc., in 1974 slaughtered over 6 percent of the total federally inspected hogs, and the plant included in this study had a kill slightly over 5 percent of all federally inspected hogs.

PROJECT GOALS

The meat industry was identified in the 1972 Act as one of 27 industries requiring standards of performance for new sources (Section 306). The listed industries, including "meat product and rendering processing", have also been covered by effluent guidelines and standards issued by the EPA. The Federal Register on February 28, 1974, published "Best Practicable Control Technology" (July 1, 1977) and "Best Available Technology" (July 1, 1983) effluent requirements for the red meat

Table 1. EMPLOYMENT IN THE MEAT INDUSTRY, FOOD INDUSTRY, AND ALL MANUFACTURING IN 1973[2]

Industry	Total employees	% of all manufacturing
Meat packing (SIC2011)	172,500	0.9
Meat processing (SIC2013)	59,000	0.3
MEAT TOTAL	231,500	1.2
All food	1,736,300	8.8
All manufacturing	19,820,000	100.0

Table 2. FEDERALLY INSPECTED SLAUGHTER IN 1974[3][a]

Species	Head killed, USDA inspection	Avg. live wt., lbs	Total LWK, millions of lbs.	% Total LWK
Cattle	33,318,000	1,052	35,050.5	63.4
Calves	2,354,000	211	496.7	0.9
Hogs	77,070,000	245.2	18,898.8	34.1
Sheep & lambs	8,556,000	105	898.4	1.6
TOTALS	121,298,000		55,344.4	100.0

[a] Federal inspection includes over 90% of all species slaughtered.

Table 3. SLAUGHTER OF HOGS IN 1974[4]

Slaughtering site	Head killed	Percent of total
Federal inspection	77,070,000	93.0
State inspection	4,705,900	5.7
Farm slaughter, est.	1,050,000	1.3
TOTALS	82,825,900	100.0

industry. These are the federal limits which are applicable to effluents from existing hog slaughtering operations.

The first objective of this project is to see what can be reasonably accomplished in a typical large hog slaughtering operation without major alterations to the plant, and with little or no hindrance to the productive output. This need to reduce in-plant waste while maintaining the usual production rate and quality requires the cooperation of the operating personnel involved and backing of management. To this end, project personnel have diligently kept line supervision informed, and meetings are held to obtain the opinions and recommendations of the people involved in any proposed change.

Other factors which are considered in project decisions are the health and safety of employees, cost effectiveness, and the measurability of any change.

The second goal of this project is to make the subsequent in-plant treatment task easier and less costly, especially as to what is required to comply with EPA Best Practicable Control Technology and Best Available Technology effluent requirements.

DESCRIPTION OF PLANTS

The Madison plant where most of the study was carried out was built originally in 1917 by the Farmer's Cooperative, and was purchased by Oscar Mayer and Company in 1919. Since its purchase, the plant has expanded more than 14 times and now includes a modern meat processing plant, spice processing and plastic production as well as a 1,000 head per hour hog kill and an 80 head per hour beef kill.

The Davenport plant was purchased in 1946 from Kohr's Packing Company. Since its purchase it has been greatly renovated and expanded. The plant combines a 750 head per hour hog slaughtering and butchering facility with a large modern ready-to-eat processed meat plant.

Beardstown was built in 1967 as a hog slaughtering and butchering facility with a capacity of 750 hogs per hour. Since the original construction, the plant has been increased in size by 40 percent to provide additional room for ham canning and other operations.

Madison Hog Kill Process

Hog slaughtering is an assembly line, or rather a dis-assembly line process (Figure 1). In Madison, the hogs are driven one at a time into a conveyorized carbon dioxide tunnel where they are anesthetized. The unconscious hogs are then dropped onto an inclined steel slat conveyor which has a stainless steel trough running along one side of it. The hogs are placed with their necks over this trough and a knife is used to cut the jugular veins and carotid arteries. The blood which is collected is pumped to a blood processing area where it is dried for use as animal feed. When the hog carcasses reach the top of the inclined bleed conveyor, they drop off into a long shallow scald tank filled with 140 degree F water and a scald aid. The carcasses are pushed the length of the tank by means of mechanical "dunkers". Total scald time is about five minutes. From the scale tank, the carcasses are conveyed into a dehairing machine where steel tipped rubber paddles strip the hair from the carcasses. The carcasses are constantly lubricated and the hair is carried away by recirculating hot water in the machine. The hair and toenails are removed and sometimes saved and sometimes discarded. From the dehairing machine, the carcasses are hung on gambrels inserted behind the achilles tendon and are hung on a live chain.

The carcasses are then dipped into a 300 degree F rosin tank and coated with rosin. The rosin is then water cooled and stripped off, taking with it some of the hair not removed in the dehairing machine. After the rosin stripping, there is a gas flame singer, a set of water lubricated scrapers and a series of workers who shave off any remaining hair before the carcasses go through a deluging shower which carries off all loose soil and hair. Once the carcass has passed this point, any remaining hair or soil has to be removed by excision. From this point, a series of workers cut off the eyelids and sever the head from the body, leaving it hung by a strip of flesh, and USDA inspectors check the salivary glands for infections. The brisket is split, the aitchbone is split, and the bladder (and uterus, if present) are removed. The anus is cut around and the abdomen is opened and the viscera removed and placed on a conveyor. The carcass is spilt through the backbone, the kidneys are freed, and some internal trimming is done before the carcasses are given a final inspection by a USDA inspector. The kidneys are removed, the head is removed, the internal fat is stripped out and scraped, the stick wound in the neck is washed, and the carcass is weighed and sent to the cooler to be held for further breakup the following day.

The viscera, after being inspected by a USDA inspector, are separated with the heart, lungs, liver, pancreas, caul fat, spleen and stomach being removed either for edible product, drug manufacturing or animal food. The large and small intestine and all condemned viscera

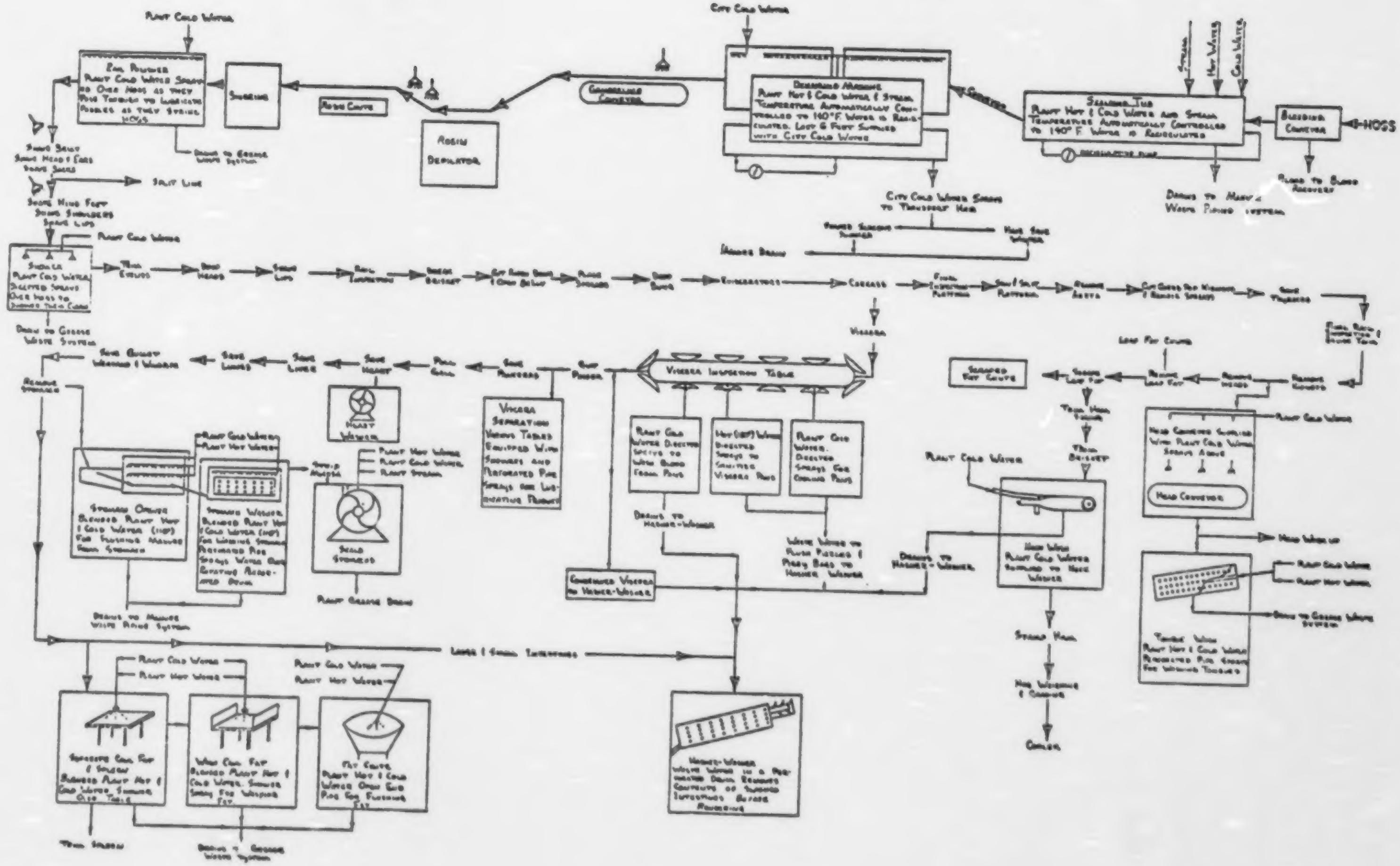

Plant Cold Water
Shaving
Rosin Chute
Rosin Depilator
Gambreling Conveyor
City Cold Water
Dehairing Machine
Plant Hot & Cold Water & Steam. Temperature Automatically Controlled to 140°F. Water is Recirculated. Lost & Fuel Supplied with City Cold Water
Scalding Tub
Plant Hot & Cold Water and Steam. Temperature Automatically Controlled to 140° F. Water is Recirculated
Steam
Hot Water
Cold Water
Bleeding Conveyor
HOSS
Blood to Blood Recovery
Drains to Manure Waste Piping System
City Cold Water Sprays to Transport Hog
Split Line
Drain to Grease Waste System
Carcass
Viscera
Viscera Inspection Table
Leaf Fat Chute
Scraped Fat Chute
Head Conveyor
Stomach Washer
Skeld Stomach
Plant Grease Drain
Heart Washer
Large & Small Intestines
Chiller

Figure 1. Process flow sheet.

are cleaned and sent to a cooker where they are processed for grease and animal feed. The muscles from the cheeks and scalp are removed from the head and the skull is split open and the hypothalamus and pituitary glands are removed and quick frozen. The skull and jaw bones are ground up and processed into animal feed.

Madison Water Supply

The water supply for the Madison plant is supplied both by wells on the property and by purchased city water. Potable water is required in all washing and cleanup operations, and 180 degree F water is used for viscera pan washing and other applications the USDA deems necessary.

Madison Waste Collection System

Madison's wastewater collection is by means of four separate systems: (1) clear water which is cooling water and roof drains, (2) sanitary drains from toilets, (3) grease, containing industrial wastewater, drains from the kill floor, cutting floor and processing plant, and (4) manure, containing industrial wastewater, drains from the stockyards, dehairing machine and stomach washer.

The clear water drains discharge to a city storm sewer and the sanitary sewage is sent directly to a city sanitary sewer. The grease and manure containing wastewater systems go through primary and secondary treatment on the premises before being discharged to an interceptor sewer of the Madison Metropolitan Sewage District.

Variances at Davenport and Beardstown

Davenport's kill floor is almost the same as Madison's except for a few differences in physical layout and brands of equipment used. Like Madison, Davenport's water is supplied both from the city and from private wells. Unlike Madison, they do no secondary treatment of plant wastes; suspended solids are removed by screening and grease flotation. The pretreated effluent is sent to the City of Davenport sewage treatment plant.

In Beardstown, the hogs are electrically stunned and shackled by one hind leg and bled over a blood collecting pit rather than on a conveyor. In Beardstown, the rosin dip is not used.

All of Beardstown's potable water supply comes from three wells located on the plant property.

Beardstown's clear water runoff is conveyed from the plant site in a drainage ditch. The grease and manure containing drainage systems, after being pretreated to remove suspended solids and grease, are combined with plant sanitary sewage and are pumped to a series of anaerobic then aerobic lagoons for final treatment before discharging to the Illinois River.

PROJECT IMPLEMENTATION

The project goals will be accomplished in three main steps: (1) characterize water use and waste generation, (2) plan, design and install process changes, and (3) recharacterize waste generation to evaluate and quantify benefits.

Special attention is given to locations on the kill floor which have the greatest potential for reduction of pollution loads through changes in work procedures, equipment, and process redesign. Care must be taken to insure that these changes do not interfere with the rate of production, the quality of the product, or the health and safety of the workers.

WASTEWATER CHARACTERIZATION

The first step in the study was to characterize the waste flows and loads generated on the kill floor. Wastes range from meat scraps to whole blood to drinking fountain water, and are generated in great variety depending upon location on the kill floor. The initial characterization is designed to quantify in sufficient detail the point discharges representing nearly all the pollution. The characterization study will then be used to direct attention to areas where profitable changes can be made and to provide a datum for later evaluation of the changes.

General Observations and Process Flow Sheet

The process flow on the kill floor was shown in Figure 1, which indicates hog carcass movement, by-product generation points, and sources of wastes. The waste collection system for the kill floor is shown in Figure 2 and includes four types of drains: hasher-washer drains, blood recovery drains, grease water drains, and manure water drains. The process flow sheet and the collection system were studied

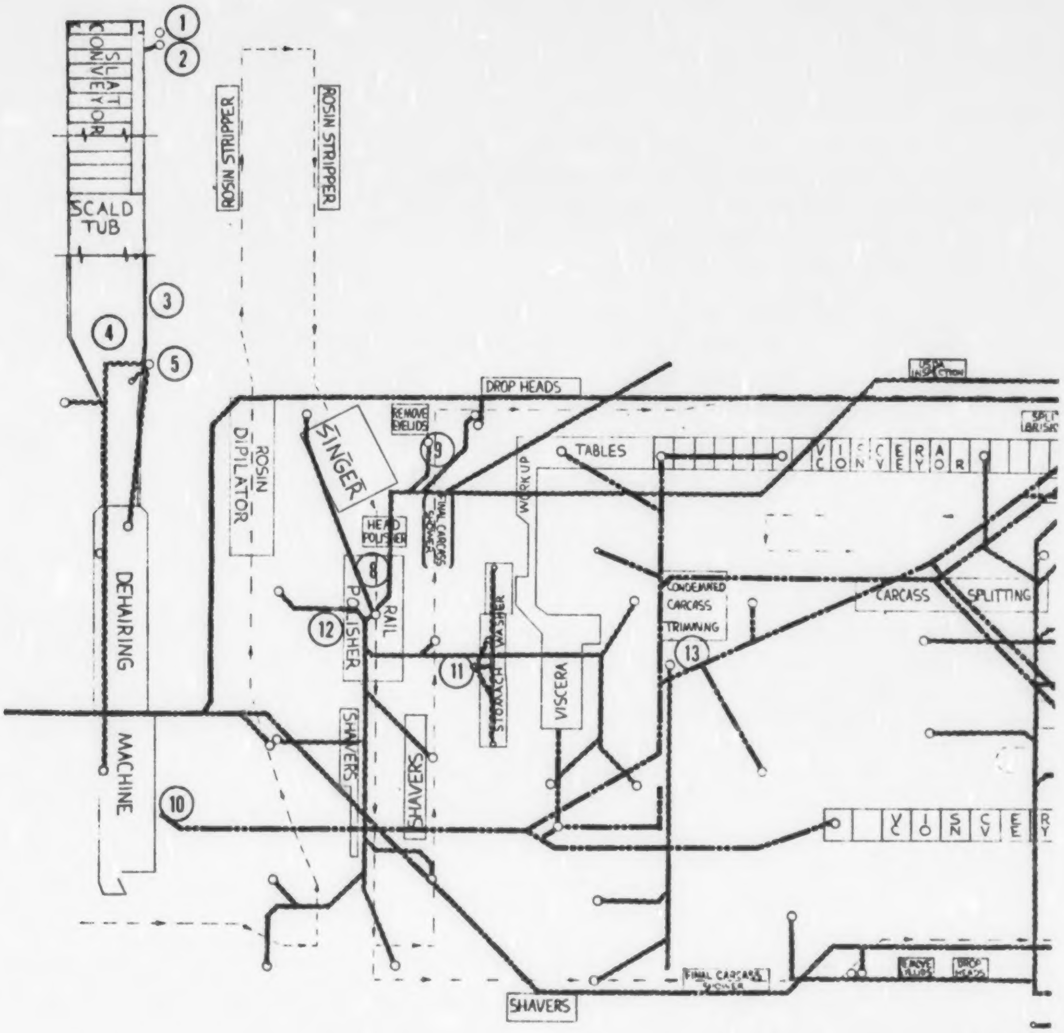
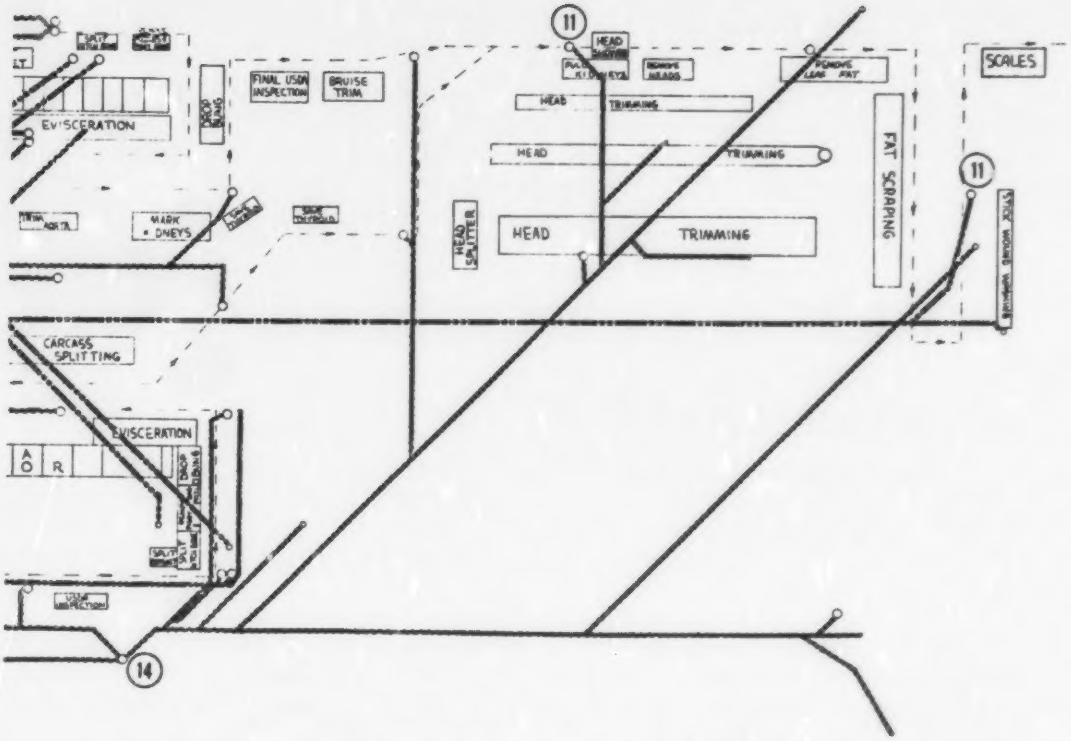

1
2
SLAT CONVEYOR
ROSIN STRIPPER
ROSIN STRIPPER
SCALD TUB
3
4
5
DROP HEADS
USDA INSPECTION
REMOVE EYELIDS
SPLIT BRISKET
ROSIN DIPILATOR
SINGER
9
TABLES
VISCERA CONVEYOR
WORKUP
FINAL CARCASS SHOWER
HEAD POLISHER
8
DEHAIRING
MACHINE
12
POLISHER
RAIL
WASHER
STOMACH
11
VISCERA
CONDEMNED CARCASS TRIMMING
13
CARCASS SPLITTING
SHAVERS
SHAVERS
10
VISCERA CONVEYOR
FINAL CARCASS SHOWER
DROP HEADS
SHAVERS

Figure 2. Madison kill floor drains.


11
HEAD SHOWER
PULL KIDNEYS
REMOVE HEADS
REMOVE LEAF FAT
SCALES
FINAL USDA INSPECTION
BRUISE TRIM
DROP RUNG
EVISCERATION
HEAD TRIMMING
HEAD TRIMMING
FAT SCRAPING
11
STICK WOUND WASHER
TRIM AORTA
MARK KIDNEYS
HEAD SPLITTER
HEAD TRIMMING
CARCASS SPLITTING
EVISCERATION
A O
R
SPLIT
USDA INSPECTION
14

Scale: ⅛" = 1'0"

KEY

▬▬	HASHER WASHER CHUTE
▬▬	BLOOD DRAIN
▬▬	GREASEWATER DRAIN
▬▬	MANURE WATER DRAIN
— - —	CENTER LINE - KILL CHAIN

and the following sampling points in the Madison plant were selected to adequately describe the waste:

1. Bleed area floor drain
2. Bleed conveyor blood drain
3. Bleed conveyor wash
4. Scald tank
5. Dehair floor drain
6. Dehair wash*
7. Hair wash drain*
8. Railpolisher
9. Carcass shower
10. Hasher-washer

11a. Stomach washer
11b. Neck washer
11c. Head washer

12. "660" grease drain
13. Center grease drain
14. "330" grease drain

*Not shown in Figure 2.

Sampling Methods

Some sample points were adaptable for automatic sampling (ISCO samplers were used), such as rinse cabinets and the bleed area. Wastes laden with heavy solids or hair were samples manually.

The location of the kill floor at the Madison plant caused several problems in sampling and making flow measurements. It was important to locate sampling points where the waste was well mixed so samples would be representative, and it was necessary to find locations to isolate waste contributions from adjoining areas. The three main grease drains were sampled from ports installed one story below the kill floor. The manure drain from the dehairing-scald tank process was sampled several stories below the kill floor. The Oscar Mayer staff played the major role in designing and installing special sampling facilities.

Parameters Measured

The following parameters were measured on all samples: total solids, total volatile solids, suspended solids, suspended volatile solids, total Kjeldahl nitrogen, total organic carbon, BOD$_5$ and COD. Grease, pH and total carbon were measured on a substantial portion of the samples as well.

All analyses were done according to the standard methods and accepted EPA methods. Quality control was checked twice by EPA standards evaluation with satisfactory results. Internal checks using split samples and duplicate samples are also used.

Flow Measurement

The individual quantification of the several hundred point sources of water on the kill floor is an impossible task. The piping distribution system which is separated to deliver three temperatures of water, is an intricate maze. The installation of water meters was only feasible on certain single high volume discharges. Those areas included dehairing machine, railpolisher and carcass shower. Several small discharges were measured with the bucket and stopwatch technique. However, the characterization of the flows combined in the various drains required the use of lithium chloride dilution technique. This technique has proven valuable in places where other flow measurement techniques cannot economically be implemented. The lithium chloride does not adsorb onto particles and the lithium can be measured in concentrations as dilute as 0.01 milligrams per liter with atomic absorption. The combination of all these flow measurement techniques has been used to measure flows for both production and cleanup shifts.

Data Analysis

Estimation of the pollution load requires careful consideration of the limitations and accuracy of the measurements to be used. This is particularly important for this study where the original load will be compared to the reduced pollution load after changes have been made.

For this study, parameters for each day of samples were estimated in terms of an average, and characterized with a standard deviation and a standard error. For each sample point the concentration data was combined with the flow data to estimate the total load from that point. Each point load was compared to the total load to determine its percent of the total load. Those points which seem to be responsible for the majority of the loadings are to be emphasized in the reduction phase of the study. Table 4 summarizes the BOD loadings from the hog slaughtering operation. Loadings are expressed as pounds of pollutant per 1,000 pounds live weight kill, a standard industry common denominator.

Sources and processes of major importance were then studied to identify poor operating procedures, sources of a particular waste, and overall reduction potential.

Data for the cleanup period is also being collected. This data will appear in the final report.

Table 4. SUMMARY OF INITIAL CHARACTERIZATION OF THE HOG SLAUGHTERING FLOOR FOR THE MADISON PLANT. PRODUCTION SHIFT VALUES ARE BASED ON AN AVERAGE KILL OF 1,253,000 LBS PER DAY.

	Flow			BOD_5			
Sample point	Gallons/ production shift	Gallons/ 1,000 lbs LWK	Percent of production flow	mg/liter	Pounds/ production shift	Pounds/ 1,000 lbs LWK	Percent of production load
1. Bleed area floor drain	-[a]	-	-	-	-	-	-
2. Bleed conveyor blood drain	-[b]	-	-	-	-	-	-
3. Bleed conveyor wash	2,550	2.04	0.75	946	20.1	0.0161	0.3
4. Scald tank	-[c]	-	-	-	-	-	-
5. Dehair floor drain	108,400	86.51	32.1	1,062	960	0.7662	15.4
6. Dehair wash drain	-[d]	-	-	1,660	-	-	-
7. Hair wash drain	-[d]	-	-	246	-	-	-
8. Railpolisher	10,960	8.75	3.2	264	24	0.0193	0.4
9. Carcass shower	(25,226)[e]	(20.13)	-	56	(11.9)	(0.0095)	-
10. Hasher-washer drain	93,800	74.9	27.8	5,860	4,580	3.66	73.7
11a. Stomach washer	12,975	10.35	3.8	1,112	119	0.095	1.9
11b. Neck washer	(1,330)[f]	(1.06)	-	3,744	(41.4)	(0.03309)	-
11c. Head washer	(6,520)[g]	(5.20)	-	-	-	-	-
12. "660" grease drain	30,140	24.05	8.9	204	51.3	0.041	0.8
13. Center grease drain	40,260	32.13	12.0	208	68.9	0.055	1.1
14. "330" grease drain	37,890	30.24	11.3	1,235	389	0.311	6.3
TOTAL	336,975	268.97	100.0		6,212.3	4.96	100.0

[a] No flow during production.

[b] Flows to blood recovery system during production.

[c] Scald tank does not drain during production.

[d] Dehair wash drain and hair wash drain are not part of the kill floor and exist only when hair is saved.

[e] Included in "660" grease drain total.

[f] Included in hasher-washer drain total.

[g] Included in "330" grease drain total.

Establishing Water Quality Requirements for Recycle

Water recycle can play a great role in pollution reduction. An integral part of this evaluation is the establishment of water quality criteria at each point for possible water reuse. Many points are eliminated as candidates for recycled water because the USDA specifies the use of potable water, but there are a few possibilities. In these cases the quality required at the use point has to be matched to that of an effluent stream. For example, if Process A can function with influent water having 200 milligrams per liter suspended solids then the effluent from Process B, which has 200 milligrams per liter or less of suspended solids, is a potential source. Quantities must be matched as well. This approach is useful in all areas of the plant.

DESIGNING PROCESS CHANGES

A plan for alterations must consider the difficulties involved in making physical changes or operational changes on the kill floor, and governmental restrictions which must be satisfied. These factors and the following points were emphasized when planning changes for this study.

Excessive Pollution Load Due to Process Design

Some processes inevitably have high pollution loads even with proper operation. For example, almost all older pieces of equipment were designed without regard for water pollution abatement. Substitutes for such processes are needed; these are being examined for productivity and quality.

Modifications of existing equipment were studied to try and obtain significant reductions at low cost. These modifications considered the redesign of spray nozzles and other water distribution mechanisms to minimize wasted water and the washing of soluble BOD down the drains.

The massive use of water for cleaning purposes in the meat industry creates excessive amounts of wastewater production. Dry collection of solids and organic material prior to wet cleaning can considerably reduce the pollution loading. A new technique being considered is vacuum cleaning of the kill floor to reduce BOD loadings to the treatment plant and to increase the input to inedible rendering.

Excessive Pollution Load Due to Improper Operation

A second type of change is needed to reduce pollution loads which are the result of improper operation or inefficient cleaning procedures. Training personnel to use proper water reduction techniques is an added supervision task. It is difficult, but critical. More recently the economic considerations for pollution treatment are forcing new operating practices to be devised and enforced. Squeeze-to-open valves are being tried to minimize excessive use of clean water by the sanitation crew. These values require the crew members to continually hold the valve open in order to obtain water.

Recycle Potential

As mentioned earlier, recycling wastewater within the plant can be a significant factor in reducing total effluent loadings. Consideration is being given to using water from a vapor phase condenser to sluice the hair in the dehairing machine, manure drain and in other similiar applications.

Governmental Restrictions

A major factor in any pollution reduction story is consideration of governmental requirements. The USDA regulations are strict in the meat industry. However, new techniques can be approved by the Technical Services Division of USDA and installed on a trial basis to evaluate reductions in pollutant production.

Quality of Product Constraints

Often a particular company will have higher standards of quality than the USDA restrictions. Implementation of ideas to reduce the pollution load must not violate these standards of quality. Some new techniques can be tried on a pilot basis prior to on-line testing. Close coordination with plant production personnel is essential to a successful modification of existing production process.

Segregation

A common tool for reducing the pollutant load is segregation and separate treatment of wastes having special characteristics. A separate blood drain will greatly aid in reducing overall pollution if this single drain can be connected to a blood recovery system. Other forms of segregation, such as grease segregation and clear water segregation should be considered.

If the waste load can be separated into a low-flow, high-concentration line and high-flow, low-concentration, great savings can be made in treatment cost. Pretreatment of low-flow, high-concentration lines will result in an overall lower cost for the final treatment process.

Complete segragation actually begins by not letting clear waters run over waste solids or wash blood into a drain. The clear water should be piped directly into the drain and the blood and solids should be dry collected for rendering.

INSTALLING PROCESS CHANGES

Once the areas which need changes have been chosen the changes must be designed and installed with a minimum of interruption of production.

The proper planning, design, and installation of proposed changes can be very imporatnt in the overall success of a pollution reduction study.

Close cooperation at all levels will insure a greater percentage of successful changes in the plant.

Some important factors considered in design and installation of a change are proper timing, reliability, the human factor, and installation.

A design change which will affect production can be accomplished very smoothly with proper coordination between production personnel. All materials should be on hand prior to starting the remodeling. A partially completed change will not help anyone.

Each company has a policy on the amount of money it usually spends in back-up equipment. A redesigned process which is good for pollution reduction but has a low reliability factor would cause management to reject the idea based on operational problems rather than technical capabilities.

A system that can reduce pollution will become ineffectual if the people who must work with it are dissatisfied and uncooperative. Consideration of human behavior is essential. Any new designs should include ways of minimizing human interference. Automatic controls can be designed, but they are expensive. A practical design combined with proper staff training and understanding can lead to better results than complicated and expensive equipment.

Proper installation is important. All necessary governmental authorization must be obtained and all safety factors must be taken into account prior to installation.

POTENTIAL IMPROVEMENTS

Based on an analysis of the flows and loads from the various discharge points shown in Table 4, areas were selected for studying potential improvements. The sources, problems, and changes under consideration are listed below (see Figure 2 for floor plan).

1. Source: Stick and Bleed Area
   Problem: Overflow of blood from the blood receiver onto the floor during operation. This blood is washed into the grease drain during cleanup.
   Potential Improvement: This situation can be corrected by redesigning the blood receiver to allow for periodic surges of blood.

2. Source: Dehairing Machine
   Problem: Presently 40,000 gallons of potable water during production and 25,000 gallons of water during cleanup are being used to transport hair to the pretreatment plant or to hair-washing.
   Potential Improvement: Replace the potable water with recycled water from the vapor phase trolley cleaning or the final carcass shower. Another alternative would be to handle the hair dry as is done in one of the other plants.

3. Source: Railpolisher
   Problem: Water runs when no hogs are in the railpolisher.
   Potential Improvement: Install a micro-switch-operated solenoid valve to turn off water when no hogs are in the railpolisher.

4. Source: Carcass Shower
   Problem: Water runs when no hogs are in the shower, and the present nozzle system wastes water by spraying water into the space between the hogs in the conveyor system.
   Potential Improvement: Install a switch-operated solenoid valve as described for the railpolisher. Redesign the nozzle system to spray only on the hogs and not between them.

5. Source: Brisket Breaking-Evisceration
Problem: Large numbers of blood clots and trimmed parts are dropped onto the floor and into the gutter. Wastewater from drinking fountains, lavatories and sterilizers wash over this material and carry soluble BOD and other pollutants to the drain. During cleanup some of the clots and fine scraps are pushed down the waste shute to the hasher-washer drain or down the grease drain. This material ultimately adds up as sewage which must be treated.
Potential Improvement: The change consists of two steps:

Step One:	Route dilute wastewaters directly into drains and away from areas of scrap and blood clots, and
Step Two:	Pick up floor scrap and blood clots with a vacuum cleaner to increase recovery of inedible scrap and reduce total pollution load from the kill floor by keeping the scrap out of the drains.

6. Source: Carcass Splitting
Problem: Bone and meat dust from carcass splitting is washed down the grease drains by dilute wastewater.
Potential Improvement: Isolate this material from wastewater streams, pick it up with the vacuum cleaner, and dispose of it into inedible rendering.

7. Source: Viscera Pans and Treadmill
Problem: Presently excess water is being used to rinse the pans during production and cleanup.
Potential Improvement: The first step in water reduction is to install more efficient cleaning nozzles for the pans and treadmill consistent with government regulations. The second step would be to install timer-controlled solenoid valves to turn off the water after production and to allow the cleanup personnel to use only the amount of water that is necessary for efficient cleaning procedures.

8. Source: Headwash
Problem: Inefficient use of water.
Potential Improvement: The headwash is not required by the USDA and it can be redesigned to activate only when a hog is in the spray area, and the nozzles can be redesigned to reduce total water usage, as mentioned in the carcass shower.

9. Source: Scraped Fat Area
Problem: Some scraped fat was landing on the floor and being washed down the drain.

Potential Improvement: An additional catch tray has been installed to minimize this problem.

10. Source: Cleanup Hoses
    Problem: Excess water is used for everyday cleanup procedures.
    Potential Improvement: Cleanup hoses will be equipped with squeeze-to-open valves on the end of the hose and with V-jet nozzles.

11. Source: Hasher-Washer
    Problem: Excess blood and scraps are entering the hasher-washer drain and ending up being discharged to the grease drains. Also the contents of the intestines are washed out and flushed down the drain.
    Potential Improvement: The vacuum cleaner technique discussed previously will reduce scraps and blood entering the system. A trial will be made to determine the effect on the inedible product by rendering the intestines without removing their contents.

These improvements require careful consideration of the consequences of any change. The cooperation of all departments affected must be enlisted before any construction begins.

RECHARACTERIZATION OF WASTEWATER

Once the desired changes are made the waste streams will be resampled and analyzed. The recharacterization data can be compared to the original data to measure the overall reduction in pollution loading. There are several factors which should be considered in evaluation of the changes.

An important factor in a comparative study is the statistical basis of comparison. It is essential that the assumptions of random samples and representative samples be met. A statistical comparison should state a level at which a researcher can show statistical confidence that there actually was a change.

Sometimes a process change or a segregation change makes resampling a particular effluent stream very difficult. A once large volume may be significantly reduced; the reduced loading may vary more than the original. The number of samples obtained must be adjusted to compensate for such a change. The process recharacterization results will be given in the project final report in a table similar to the original characterization data (Table 4).

ECONOMIC EVALUATION

The cost/benefit analysis of a pollution reduction program for an industry is a crucial step in the study. The cost of organizing a study and implementing a proposed change must be weighted against the benefits of lower water bills, reduced sewer charges, reduced treatment costs, and increased by-product recovery. The cost/benefit analysis must be considered for several years into the future. The uncertainty of future costs for raw water and wastewater treatment makes the analysis very difficult and requires careful judgement by the industry.

An industry may be considering several changes to reduce pollution load and conserve water. Each alternative can be evaluated by a systematic approach as outlined in Figure 3.

The first step for the industry is to realize that a pollution problem exists, or that a savings can be made by reducing its total effluent load. This may take the form of a violation of an effluent constraint or excessive surcharges.

Secondly, the industry must survey the in-house operations to pinpoint major problem areas and sources for potential improvement. The most difficult decision facing the industry is selecting the change which will have the greatest benefit, in the form of pollution reduction, at the lowest cost.

The third step requires the industry to make a detailed analysis of the present treatment and disposal costs (C_1). This is the basis for comparison for the revised costs. In this study the industry operates a primary and secondary treatment facility and discharges the treated effluent into a municipal sewage district interceptor. Other industries may have complete on-site treatment or may discharge the total effluent to a sanitary district. In all cases the present cost of disposal, the method used for calculating that cost, and an estimate of future changes in those costs should be understood.

The fourth step involves studying each proposed modification and estimating the pollution reduction and water conservation that can be achieved. The reduced effluent load is used for calculating the revised treatment cost (C_{tr}), the cost for installing and operating the modification (C_m). Also, any benefits (B) due to reduced raw water volumes and by-product recovery can be calculated.

In step five the cost of the modification is added to the revised treatment cost and any benefits are subtracted from this total.

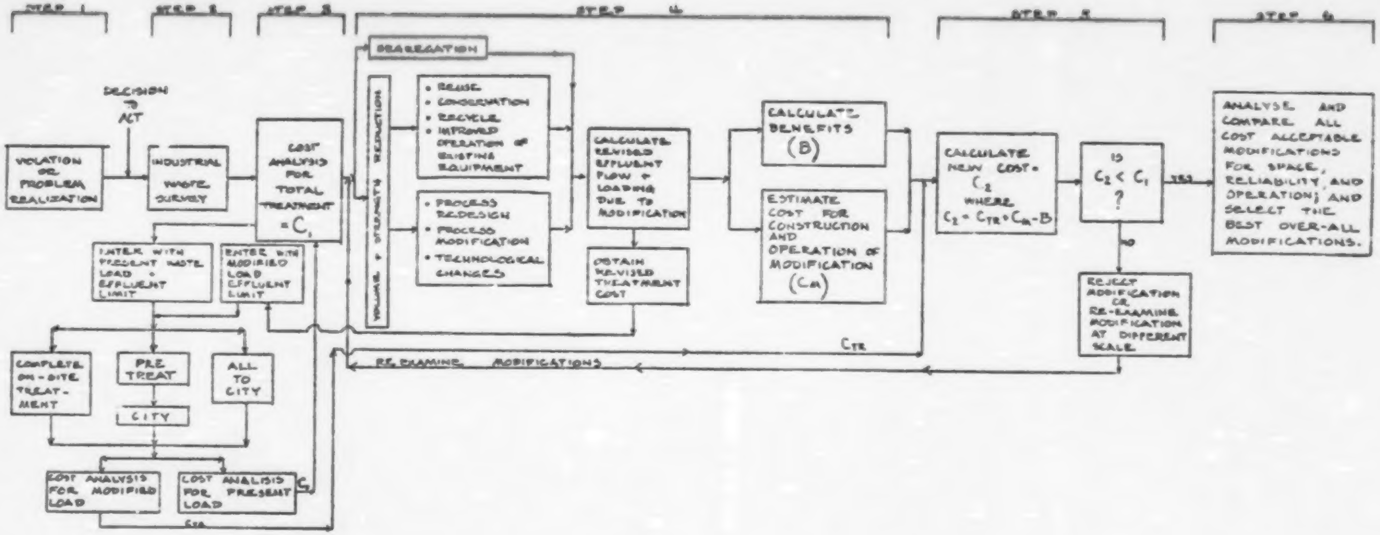

STEP 1
STEP 2
STEP 3
STEP 4
STEP 5
STEP 6
VIOLATION OR PROBLEM REALIZATION
DECISION TO ACT
INDUSTRIAL WASTE SURVEY
COST ANALYSIS FOR TOTAL TREATMENT = C_1
INTER WITH PRESENT WASTE LOAD + EFFLUENT LIMIT
ENTER WITH MODIFIED LOAD EFFLUENT LIMIT
COMPLETE ON-SITE TREAT-MENT
PRE TREAT
CITY
ALL TO CITY
COST ANALYSIS FOR MODIFIED LOAD
COST ANALISIS FOR PRESENT LOAD
C_1
C_{TR}
SEGREGATION
VOLUME + STRENGTH REDUCTION
• REUSE
• CONSERVATION
• RECYCLE
• IMPROVED OPERATION OF EXISTING EQUIPMENT
• PROCESS REDESIGN
• PROCESS MODIFICATION
• TECHNOLOGICAL CHANGES
CALCULATE REVISED EFFLUENT FLOW + LOADING DUE TO MODIFICATION
OBTAIN REVISED TREATMENT COST
CALCULATE BENEFITS (B)
ESTIMATE COST FOR CONSTRUCTION AND OPERATION OF MODIFICATION (C_M)
C_{TR}
RE-EXAMINE MODIFICATIONS
CALCULATE NEW COST = C_2 WHERE $C_2 = C_{TR} + C_M - B$
IS $C_2 < C_1$?
YES
NO
REJECT MODIFICATION OR RE-EXAMINE MODIFICATION AT DIFFERENT SCALE
ANALYSE AND COMPARE ALL COST ACCEPTABLE MODIFICATIONS FOR SPACE, RELIABILITY, AND OPERATION; AND SELECT THE BEST OVER-ALL MODIFICATIONS.

Figure 3. Systems approach to optimizing industrial waste treatment costs.

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$$C_{tr} + C_m - B = C_2$$

This new cost (C_2) is compared to the original total cost (C_1); if C_2 is less than C_1, a savings can then be made by installing the modification. If the new cost is greater than the original cost the modification can be rejected or reexamined at a different scale. For example, if a segregation modification is rejected a more complete segregation alternative can be examined.

In step six the modifications which proved viable are compared and the ones with the best cost/benefit analysis are chosen if they also satisfy the company's requirements for space, base of operation, reliability and other factors. The best judgment of the industry must be used to select the modifications which will achieve a least-cost, long-run solution to its pollution problem.

CONCLUSION

The selection of alternative methods for reducing wastewater from in-plant hog slaughtering operation requires a careful examination of the process flow diagram, the wastewater collection system, the characteristics of the wastewater and the existing treatment system. This information is the basis for comparing new improvements and their relative effect in treatment performance and costs. In the first phase of this study the problem areas of the hog slaughtering operation have been isolated and quantified. More data for the kill shift and the cleanup shift is now being analyzed.

The next phase of the study will include installing modifications and recharacterizing the modified effluents to determine the degree of wastewater reduction achieved. Estimating the effect of these reduced loads on existing wastewater treatment costs is a difficult task, and will require careful study of the basic factors which control wastewater treatment costs. Industries which have complete discharge to a municipal sewage district may be able to estimate potential savings more accurately based on existing surcharge rates.

The final report for this project will include several detailed examples of potential modifications and the economic and operating feasibility of each.

ACKNOWLEDGEMENTS

This paper presents a preliminary report on progress to date under EPA Grant R802833-01 to the University of Wisconsin-Madison entitled "Characterization and Reduction of Specific Wastewaters from In-Plant Hog Processing Units of the Meat Industry". Oscar Mayer and Company, Inc., with general offices at Madison, Wisconsin, holds a subcontract on this project and provides both facility and technical support. Work on this project has taken place within the hog slaughtering facilities at the Oscar Mayer and Company plants located at Beardstown, Illinois; Davenport, Iowa; and Madison, Wisconsin.

In addition to acting as a subcontractor, Oscar Mayer and Company has provided certain matching funds to support the project.

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EGG PROCESSING WASTE RECOVERY

N. Ross Bulley*

INTRODUCTION

Most food processing operations generate a waste effluent which contains diluted edible material. Operations such as conveying, mixing, peeling, cutting, cooking, sterilizing and packaging all convert some useable food material into a form which in many cases is considered unfit for human consumption. The product may be considered a waste because of palatability, microbiological, or economic reasons.

Even with all the rhetoric about preserving the environment, the waste handling method chosen by most processors will be the one which is cheapest and will still meet the pollution control standards set for his operation. The egg processing industry will be no different in this respect from any other industry. The first consideration for any waste treatment system should be to minimize waste production and water use and to maximize water reuse through partial purification and recycling. The next consideration should be for potential product recovery from waste streams followed by final treatment and disposal.

Our first studies on the handling of egg processing wastewater were centered on an aerobic treatment method using an extended aeration system.[1]

While carrying out this research in our laboratory, it was felt that since a large fraction of the solids in the wastewater was pure egg albumen and yolk, a chemical precipitation or some other form of treatment should remove a large portion of this high protein waste. This could significantly reduce the size of any subsequent waste treatment system which might be required and should produce a saleable product. The other main sources of waste from this food processing system are the egg shells with the albumen which adheres to the shells

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during the breaking operation. This waste if dried should produce a potentially saleable product as a feed additive for poultry.

The purposes of this research were (1) to investigate the feasibility of pretreating the processing wastewater for removal of the egg solids, and (2) to study the problems and potential returns from drying of the egg shells with their associated albumen.

EGG PROCESSING: WASTEWATER SOLIDS RECOVERY

Characteristics

The characteristics of the wastewater generated from the breaking and processing operations vary from plant to plant but typical characteristics are shown in Table 1.

These waters will vary considerably throughout the day depending on methods of water reuse, detergents used in egg cleaning and any waste slug loads released during or at the end of a processing operation. The colloidal nature of the egg wastewater makes solids removal by clarification almost impossible.

Solids Recovery Systems

Chemical Coagulation---Aluminum ions are used in many physical-chemical treatment systems to aid in solids removal. Laboratory tests were conducted on the processing wastewater to determine the effect of pH and alum concentration on egg solids coagulation. If the wastewater was left untreated for 24 hours there was very little coagulation and no noticeable settling. The addition of aluminum sulfate accompanied by a pH adjustment did produce a settleable floc. Typical results are shown in Table 2. The pH of the original waste varied from 10 to 11.5 and was adjusted to pH 5.1 for maximum floc formation using 3N H_2SO_4. Solids coagulation and settling varied to some extent for different concentrations of alum but the removal was always greater than 50 percent for alum concentrations above 200 parts per million. Below 200 parts per million, the solids removal efficiency dropped significantly. The percentage of solids which coagulated and settled increased with decreasing solids concentration (Table 3). The very high solids removal efficiencies for solids concentration less than 1,000 parts per million indicated that a second addition of alum to the supernatant might increase solids removal.

Table 1. TYPICAL EGG GRADING AND PROCESS WASTEWATER CHARACTERISTICS

Analysis	mg/l
BOD_5	6,300
COD	9,780
Total solids	6,950
Kjeldahl-N	537
NH_4^+-N	48
NO_3^--N	2
$PO_4^{\equiv}$-P	144

Table 2. EFFECT OF ALUM CONCENTRATION ON EGG SOLIDS REMOVED

$Al_2(SO_4)_3$, ppm	Total egg solids, ppm			% Solids removed	
	Wastewater	Supernatant			
		1[a]	2[b]	1	2
600	4,130	1,339	1,179	68	71
400	4,130	2,107	1,767	49	57
200	4,130	1,855	1,552	55	62
100	4,130	2,744	2,508	33	39
50	4,130	3,074	2,917	26	30

[a] Fresh waste.

[b] Five-day old waste.

Table 3. EFFECT OF EGG SOLIDS CONCENTRATION ON SOLIDS REMOVAL EFFICIENCY $Al_2(SO_4)_3$ ADDITION TO GIVE 200 PPM IN WASTEWATER

Total solids wastewater ppm	Total solids in supernatant, ppm	% Removal	BOD_5, ppm Before clarification	BOD_5, ppm After clarification	BOD_5, ppm % Removal
6,147	3,836	37.6			
4,265	2,288	46.4	3,535	720	79.6
3,073	1,116	63.7			
2,132	876	58.9	1,240	390	68.6
1,537	816	46.9			
1,066	368	65.5	640	75	88.0
1,024	236	77.0			
768	152	80.0			
711	68	90.0	552	60	89.1
533	40	92.0	470	57	88.0

The addition of a second 200 parts per million alum to the supernatant from the first clarification (2,288 parts per million egg solids remaining) resulted in the formation of a second floc which removed an additional 15 percent of the egg solids. This indicated that most of the remaining solids were in a form which could not be readily removed by flocculation. The BOD_5 removal accompanying the flocculation and solids removal varied from 70 to 90 percent. Over 95 percent of the $SO_4^=$ remains in solution and does not become associated with the floc. Greater than 90 percent of the added aluminum is removed in the floc. The floc when dried contained about 10,000 parts per million aluminum on a dry weight basis. Feeding trials should be conducted on the waste material to determine its acceptability as a feed additive. Previous feeding trials using a fish processing waste with aluminum concentrations in this order did not present any feeding problems when the waste represented up to 5 percent of the total ration.[2]

Electrocoagulation

Because of the proteinaceous characteristics of the waste materials in the wastewater, it was felt that the colloidal nature of the waste might lend itself to treatment by electrocoagulation. A laboratory batch treatment system was studied. Two aluminum electrodes (abour 20 square centimeters surface area each) were placed in 100 milliliters of waste in beakers and a 20 volt D.C. potential applied. The effects of time, temperature, electrode surface area, electrode separation, pH and waste concentration on floc formation and settling were studied.

A floc forms on the anode immediately with a gas being released from the cathode. The floc had a tendency to adhere to the electrode with a resulting decrease in current. Tapping the electrodes gently released the floc and it floated to the surface forming a whitish froth. The current varied from 100 to 400 milliamperes (ma) with the irregular release of the floc but averaged about 250 ma.

The solids removal efficiency was found to have a non-linear response with time as shown in Table 4. The reproducibility after 10 minutes was found to be very poor and varied from 30 to 50 percent removal. This is most probably attributable to the very simple apparatus being used which was not able to keep the distance between the electrodes perfectly constant and was unable to remove the floc from the surface of the anode in a reproducible manner.

The experiments did show that a very high proportion of the effluent solids (60 to 70 percent) could be removed as a floc within 15 minutes. The concentration of the solids in the floc, if skimmed from the surface, was 2.3 percent total solids. This concentration increased

Table 4. EGG PROCESSING WASTEWATER SOLIDS REMOVAL DURING ELECTROCOAGULATION

Time, minutes	Total solids in solution, mg/l	Solids removal as floc, %
0	4,450	0
5	3,630	18
10	3,140	30-50
15	1,604	64
20	1,150	74
25	850	81
30	815	82
45	560	87

to about 3 percent solids if the batch electrocoagulation continued for 25 minutes. This solids concentration might be increased due to compaction of this floc during a commercial electrocoagulation process as has been found for other food wastes.[3]

All of the floc was observed to form on or near the anode. A clear region could be seen extending from the cathode during the treatment. The pH in this region was found to be very high (pH greater than 12) and was probably the result of the build-up of OH^- around the cathode as hydrogen ions were being neutralized and released as hydrogen gas. There was a relatively high average rate of attrition for the anode (1 milligram per minute). Using carbon electrodes also resulted in the formation of a floc on the cathode indicating that aluminum ions were not necessary for floc formation. But, the floc formed faster, required less power and seemed more stable when the aluminum cathode was used indicating an interaction of the aluminum ion with the floc. Further studies on the choice of electrode material and ion interaction are required before a pilot scale testing of the system should be attempted.

Varying the pH of the wastewater at the start of the experiment from 4.0 to 9.5 had no significant effect on the floc formation and solids removal after 10 minutes. Increasing the wastewater temperature from 20 degrees C to 49 degrees C increased the floc formation and solids removal in the first 5 minutes of electrocoagulation from about 18 to 35 percent solids removal but this advantage was lost within 15 minutes after which time there was a slight reduction in solids removal at the higher temperature. Since normal coagulation of albumen begins around 60 degrees C, it appears that additional heating of the wastewater to enhance the electrocoagulation process is unwarranted. Higher temperatures closer to the natural coagulation temperature could give very different results.

Optimum electrode materials and surface area spacing, arrangement and voltage, all should be investigated before the practical use of the electrocoagulation process can be determined for egg processing wastewater.

Based on our results, electrocoagulation is able to remove a high percentage of the egg solids producing a very stable and easily managed floc. Further studies should be carried out in this area.

EGG PROCESSING: SHELL DRYING

Samples of egg shells were collected from a commercial egg breaking machine. The shells were allowed to drain and then dried in a tray drier ($\simeq$ 140 degrees F) and weighed at intervals to obtain a drying curve (Figure 1). Samples of these dried shells were then further dried in a 105 degree C oven to obtain their bone dry weight. These shells were then boiled in 0.625 M NaOH to remove any adhereing albumen, cuticle, and membrane. The shells were then filtered, dried and weighed to find the amount of protein associated with the shell.

The materials balance on the waste stream from the egg breakers is shown in Figure 2. The stream includes the shells, adhering albumen, and the albumen removed from the individual egg inspection trays by a fine spray wash. The waste stream does not include any of the rejected eggs. The balance shows that even though the shells are allowed to drain, the bulk of the protein still sticks to the surface of the shell. This shell-albumen mix is very messy to handle and to dry but as the moisture content drops below 15 percent, the membranes become brittle and break up leaving a material that has a relatively heavy shell fraction and a light powdery membrane fraction. This light fraction will require some form of dust collection system to avoid protein loss and to prevent air pollution during the drying operation.

Feed trials should be conducted to determine the acceptability of the dry shell-albumen mix as a feed ingredient for poultry. Waste recovery systems are on the market for removing some of the free albumen from the shells in the wet state, but some problems have been experienced with their operation. The finely ground egg shell which results from these separators is considered undesirable as a poultry feed by some growers.

For a processing plant handling 600 cases of eggs per day (30 dozen eggs per case) the shell with its associated albumen after drying amounts to about 3,000 pounds of product. This is excluding the albumen when it is removed during draining and includes 450 pounds of egg solids which are about 70 percent protein.

The economics of drying the shell-albumen fraction have not been included in this paper due to the variety of drying systems possible and the very rapid changes in the cost of energy. But, based on the cost of energy for drying at $1.00 per 1,000 cubic feet of natural gas and using 2,000 BTU's per pound of water removed, the cost of energy for removing the water from the shell-albumen stream would amount to about 1¢ per pound of dry product. This appears to be low enough to encourage further study in this area.

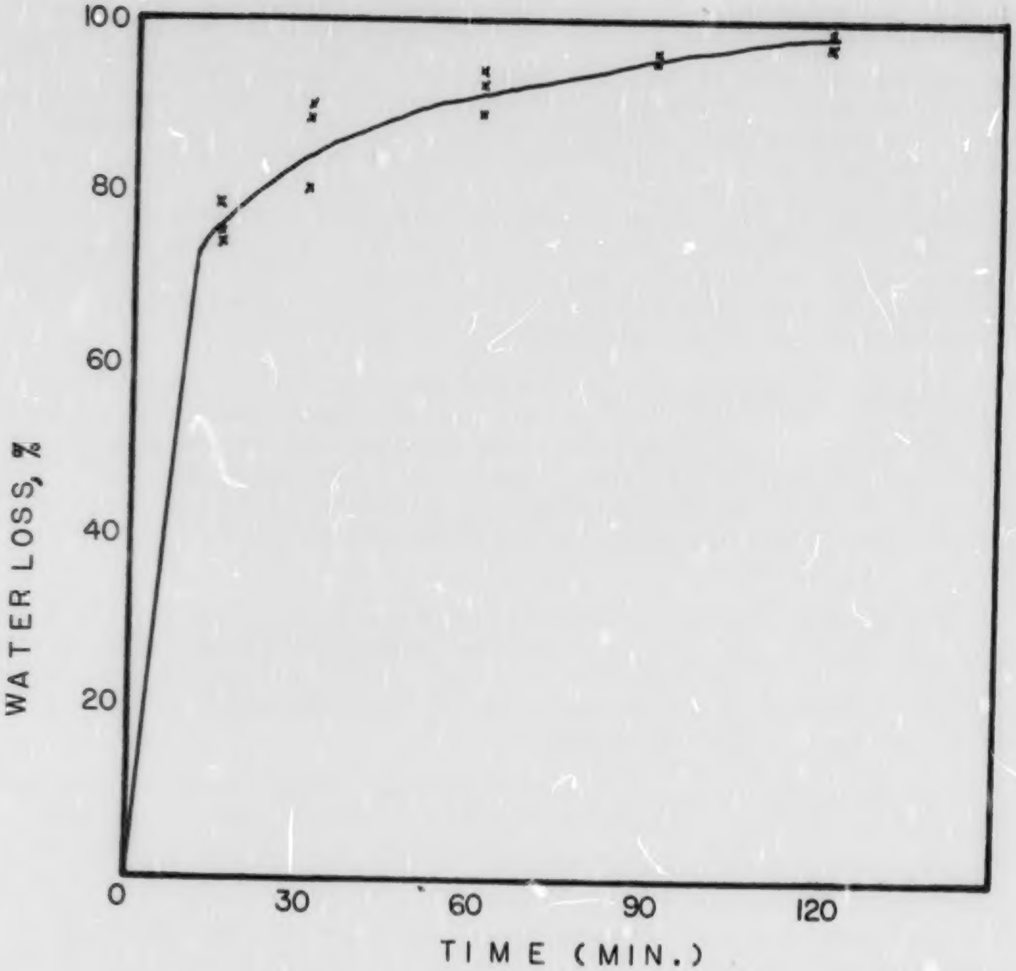

Figure 1. Water loss from albumen-shell mix in forced air drier (140°F).

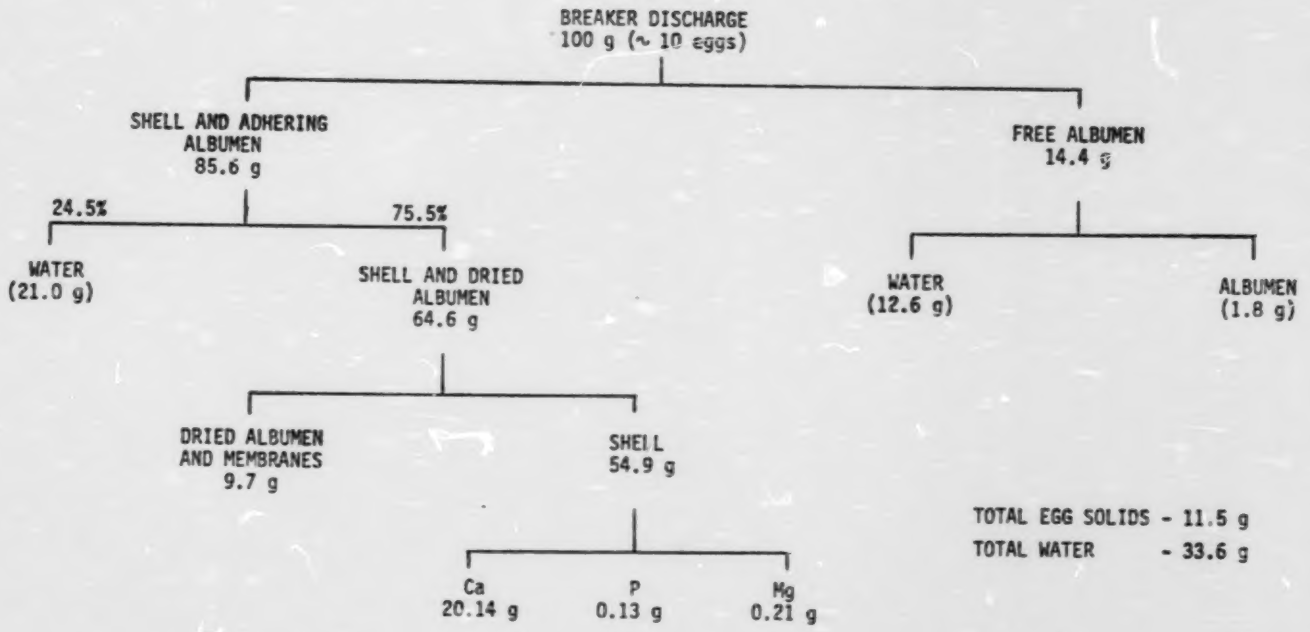
BREAKER DISCHARGE
100 g (~ 10 eggs)
SHELL AND ADHERING ALBUMEN
85.6 g
FREE ALBUMEN
14.4 g
24.5%
75.5%
WATER
(21.0 g)
SHELL AND DRIED ALBUMEN
64.6 g
WATER
(12.6 g)
ALBUMEN
(1.8 g)
DRIED ALBUMEN AND MEMBRANES
9.7 g
SHELL
54.9 g
Ca
20.14 g
P
0.13 g
Mg
0.21 g
TOTAL EGG SOLIDS - 11.5 g
TOTAL WATER - 33.6 g

Figure 2. Profile of egg breaker waste discharge for about ten eggs.

CONCLUSIONS

Methods are available for removing or reducing the waste content of effluent streams from egg processing plants.

The addition of 200 parts per million alum to egg processing wastewaters at pH 5.1 produces a settleable floc. The egg solids removal efficiency resulting from the settling of this floc is a function of initial solids concentration and is in order of 50 percent for a typical egg processing wastewater. The BOD_5 removal efficiency is less dependent on initial BOD_5 concentration and is in the order of 70 percent or greater. Electrocoagulation of the wastewater produces a stable floating floc and can remove a large percentage of the total egg solids in a relatively short time.

Drying of the broken egg shells with their associated albumen would appear to represent a viable alternative for handling this particular waste stream.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the partial funding of the project by the British Columbia Department of Agriculture and the technical assistance of Miss Judy Schweb.

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ROTATING BIOLOGICAL SURFACE TREATMENT OF VEGETABLE CANNING PROCESS WASTEWATER

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INTRODUCTION

A one-season pilot plant study was initiated on March 21, 1974, by the Environmental Pollution Control (EPCO) Division of the George A. Hormel Company of Austin, Minnesota. The study was designed to determine the effectiveness of the rotating biological surface (RBS) process when used for the treatment of vegetable canning process wastewater.

All phases of the study were conducted in Owatonna, Minnesota, on process wastewater discharged by the Owatonna Canning Company. The facility in Owatonna, which is located approximately 70 miles south of Minneapolis, cans asparagus, peas, beans, corn, and pumpkin on a seasonal basis and cans beef stew year-round.

Three RBS pilot plants identified as "polyplant-1", "polyplant-2", and "lagplant" were used during the study. Polyplants received screened process wastewater. Effluent from a three-acre, 10 million gallon anaerobic lagoon, which is the first stage of the Owatonna Canning Company wastewater treatment system in Owatonna, was treated with the lagplant (see Figure 1). Polyplant-2 and the lagplant were not available until August of 1974, but polyplant-1 was used throughout the study.

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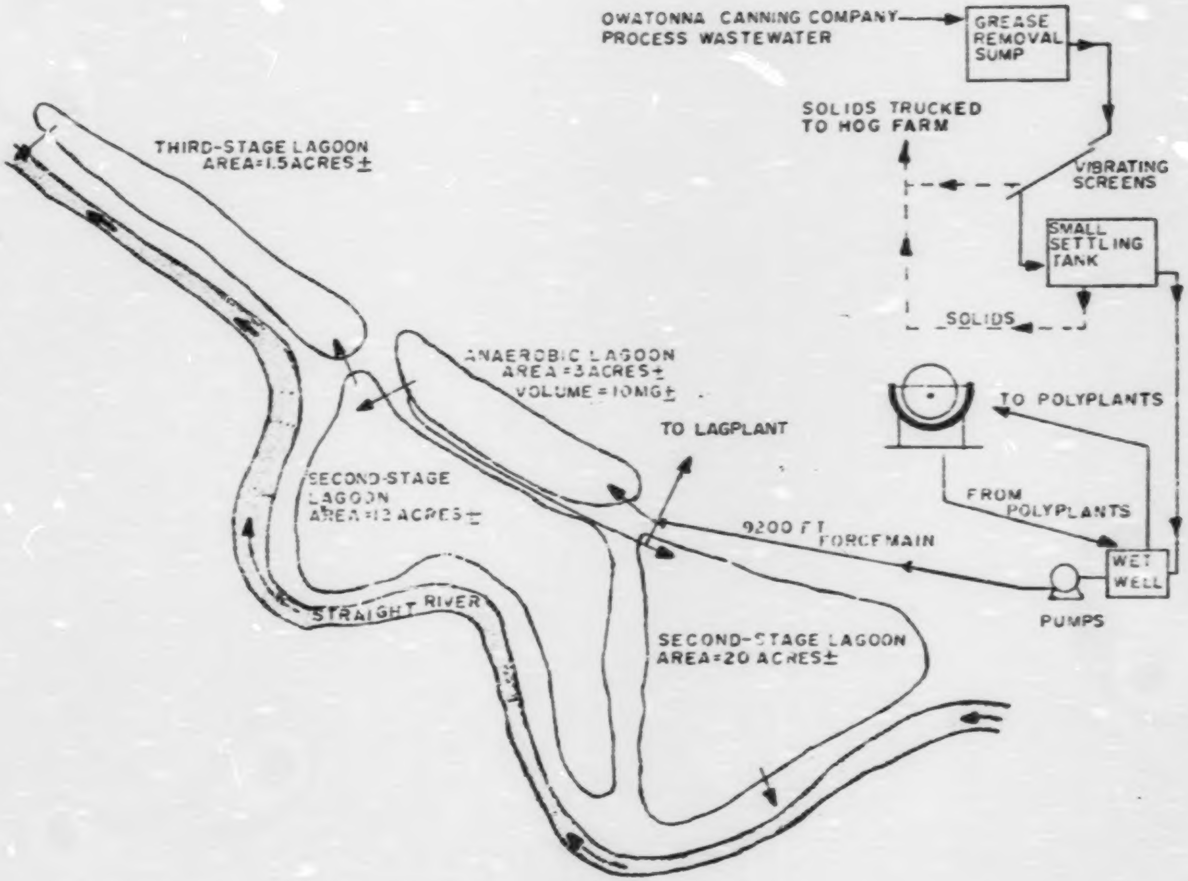

OWATONNA CANNING COMPANY PROCESS WASTEWATER
GREASE REMOVAL SUMP
SOLIDS TRUCKED TO HOG FARM
VIBRATING SCREENS
SMALL SETTLING TANK
SOLIDS
TO POLYPLANTS
FROM POLYPLANTS
WET WELL
PUMPS
9200 FT FORCEMAIN
TO LAGPLANT
THIRD-STAGE LAGOON AREA=1.5ACRES±
ANAEROBIC LAGOON AREA=3ACRES± VOLUME=10MG±
SECOND-STAGE LAGOON AREA=12 ACRES±
SECOND-STAGE LAGOON AREA=20 ACRES±
STRAIGHT RIVER

Figure 1. Schematic of water pollution control facilities at Owatonna Canning Company, Owatonna, Minnesota.

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The EPCO Division of the George A. Hormel Company retained the consulting engineering firm of Rieke Carroll Muller Associates, Inc., to reduce all data generated during the study, and to prepare final reports on the study. Pilot plant study results were presented in two reports. The first, or Phase I report, which was completed on November 22, 1974, evaluated data acquired from polyplant-1 for the period of April 5, 1974 to June 27, 1974. During this time beef stew and asparagus were being canned at the Owatonna Canning Company. The second (Phase II) report, evaluated data acquired from all three pilot plants for the period August 11, 1974 to November 13, 1974. Various combinations of corn, green beans, pumpkin, and beef stew were being canned during the second phase of the study.

Facilities Description

Each RBS unit was housed in a prefabricated metal shed with an inside covering of urethane foam insulation. Each utilized a semi-cylindrical tank 4.23 feet long and 4.0 feet in diameter for a flow-through chamber. The tank was divided into four equal-volume compartments by means of 1/4-inch partitions. Eight 47-inch diameter rotating discs per compartment were mounted on a center drive shaft so that approximately 29 percent of the disc surface area was submerged in the tank contents. A pilot unit contained a total of 771 square feet of surface area, with approximately 193 square feet in each of the four stages.

Connections between the compartments or stages permitted four-stage series operation with flow parallel to the flat sides of the rotating discs. These connections were made by means of external pipes which bypassed the compartment partitions on the outside of the tank. Samples of the effluent from each compartment were withdrawn by tubing pumps (multichannel peristaltic cassette pumps) connected to these pipes by means of plastic tubing. Figure 2 is a schematic diagram of a typical pilot plant unit.

It was necessary to pump wastewater to each of the pilot RBS units. To solve problems that were primarily caused by floatable solids present in the wastewater, a two-compartmented (in series) primary clarifier was installed ahead of the two polyplants prior to Phase II of the study. A centrifugal pump took suction from the Owatonna Canning Company process wastewater wetwell and discharged into the first compartment of the clarifier. Wastewater pumpage exceeded the requirements of the two pilot plants; the excess overflowed the clarifier and returned to the wetwell. The rotary gear pumps that fed polyplant-1 and polyplant-2 took suction from near the bottom of the second clarifier compartment. The capacity of each clarifier compartment was 183 gallons.

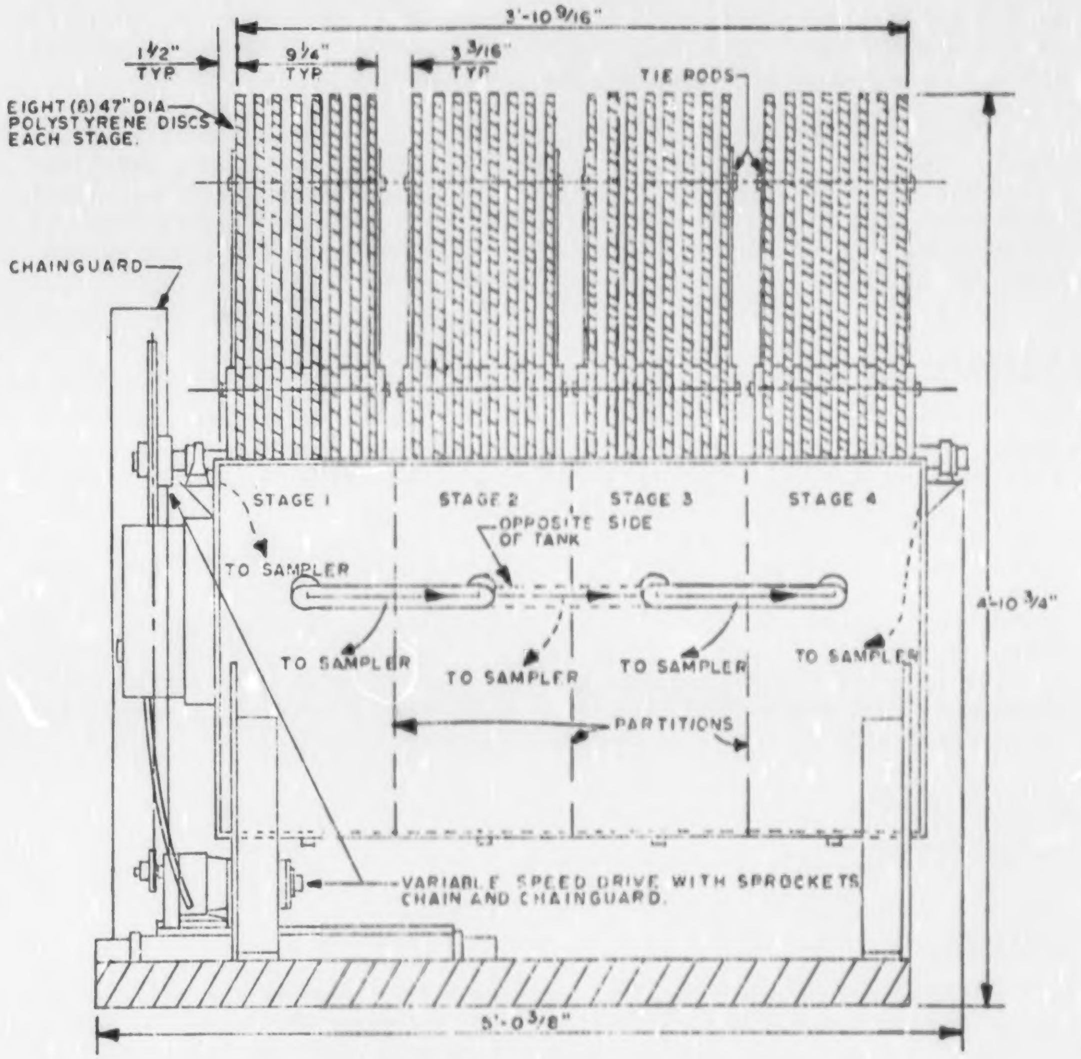
3'-10 9/16"
1 1/2" TYP
9 1/4" TYP
3 3/16" TYP
TIE RODS
EIGHT (8) 47" DIA POLYSTYRENE DISCS EACH STAGE.
CHAINGUARD
STAGE 1
STAGE 2
STAGE 3
STAGE 4
OPPOSITE SIDE OF TANK
TO SAMPLER
TO SAMPLER
TO SAMPLER
TO SAMPLER
TO SAMPLER
PARTITIONS
VARIABLE SPEED DRIVE WITH SPROCKETS CHAIN AND CHAINGUARD.
4'-10 3/4"
5'-0 3/8"

Figure 2. RBS pilot unit utilized during the RBS study at Owatonna Canning Company.

Since the lagplant received lagoon effluent which was devoid of large particles, no clogging problems were experienced with this pilot unit. Anaerobic lagoon effluent was pumped to the first stage of the lagplant by means of a rotary gear pump. Lagplant flow was maintained at 0.2 gallons per minute from August 11, 1974 to September 16, 1974 and at 0.5 gallons per minute from September 17, 1975 to October 11, 1974 at which time the lagplant was shut down.

Throughout the entire study period flows were checked on the pilot plants two to three times each sample period by means of a one-liter graduated cylinder and a stop-watch. In addition, Stevens level recorders were used in conjunction with weirs on the effluents from all pilot units to continuously record flow rates throughout the entire 24-hour sample period.

Wastewater Types

Various types of pilot unit influent were encountered during the study. Initial study results were obtained during the canning of beef stew and asparagus. A combination of beef stew and corn canning process wastewater was treated from August 11 to August 19, 1974. To this combination was added green bean canning wastes on August 19, and the three were processed together until September 9, 1974. Beef stew canning was temporarily discontinued on Septmber 9, 1974. Corn and green beans were processed from September 9, 1974 until September 21 when the corn and green bean packs ended. Beef stew canning resumed, and on September 24 the pumpkin pack began. Pumpkins were canned until October 4, 1974 after which time only beef stew was canned through the termination data of the pilot study.

PROCEDURES

Operation

Preliminary plans were to sequentially operate the pilot plant units as 4.0, 5.0 and 6.0 revolutions per minute to determine plant performance-revolutions per minute relationships, but the development of oxygen limiting and perhaps septic conditions while operating polyplant-1 at 4.0 revolutions per minute in the Phase I portion of the study necessitated an early increase in speed of disc rotation. It was found that operation at 8 revolutions per minute would maintain adequate dissolved oxygen under all conditions. Polyplant-1 was changed from 4 to 8 revolutions per minute on April 13, 1974, and all units were operated at 8 revolutions per minute for the remainder of the study period.

It is noted that the velocity of a point on the outer edge of a 4-foot diameter disc is equal to the velocity of a point on the outer edge of a full-scale 11-foot diameter disc when the rate of rotation of the small disc is 2.75 times the rate of rotation of the large disc. This relationship makes it necessary to operate small disc pilot units at a relatively high revolution per minute to simulate shear and turbulence conditions encountered in full size units operating at a lower revolution per minute. Since full scale RBS units often operate in the range of 2 to 3 revolutions per minute, it was not unrealistic to operate the pilot units at 8 revolutions per minute.

From August 11, 1974 to September 16, 1974 the flow rates were maintained with minimal fluctuations at 0.2 gallons per minute to polyplant-1 and at 2.0 gallons per minute to polyplant-2. On September 17, 1974 the flows were changed to 0.5 gallons per minute for polyplant-1 and 1.0 gallons per minute for polyplant-2. These flows were maintained (except for times when pumpkin wastes caused clogging problems) until November 13, 1974 at which time the project was terminated.

Sampling and Analyses

Three 24-hour composite samples were collected each week from five sampling points per pilot unit, which included the pilot plant influent and the effluent from each of the four stages of all units. Samples were collected with multichannel peristaltic cassette tubing pumps through plastic tubes connected to the sample points. Samples were discharged to one-gallon plastic containers packed in ice. The low-rate sampling pumps worked continuously to collect approximately one gallon of sample per sampling point during each 24-hour period. The positive displacement characteristics of the tubing pumps permitted operation that was relatively trouble free. Upon completion of each sampling period, the samples were promptly delivered to the laboratory for analyses. An independent laboratory, Minnesota Valley Testing Laboratories, Inc., of New Ulm, Minnesota, was retained to collect all samples, maintain sampling equipment, and handle all necessary field work.

Temperature and dissolved oxygen (DO) levels were determined on pilot unit influents and in each stage about mid-morning the day before each sample run and again during the day of sampling. Dissolved oxygen determinations were made in the field with a Yellow Springs Inst. Co. analyzer.

On sampling days a detailed verbal description of the growth on each of the four stages of each pilot unit was recorded by the independent laboratory service field man.

All routine laboratory analyses were performed by an independent testing laboratory; Minnesota Valley Testing Laboratory, Inc., of New Ulm, Minnesota during Phase I of the project. Beginning August 11, 1974 all such analyses were performed in the George A. Hormel Company laboratory at Austin, Minnesota by Hormel personnel.

Since intermediate or final sedimentation basins were not used in the pilot plant study, it was necessary for efficiency determinations to simulate a clarification system by settling samples in the laboratory prior to analyses. Whole influent samples and laboratory settled effluent samples from all stages were analyzed. Supernatant was withdrawn from Imhoff cones after one hour of settling for analyses on all stage effluent samples.

All laboratory determinations were performed in accordance with Standard Methods for the Examination of Water and Wastewater, thirteenth edition. Routine laboratory work included BOD, COD, Kjeldahl, ammonia, and nitrate nitrogen; phosphorus; and solids analyses.

RESULTS

Polyplant performance evaluations were based upon 25 24-hour composite samples collected during Phase I of the study, and 57 24-hour composite samples collected during Phase II. Lagplant performance was monitored by collecting and analyzing 21 24-hour composite samples.

Biomass Description

Trends in biogrowth included changes in growth thickness, evenness, texture, and coloration. Variations in biogrowth from stage to stage were normally apparent. Typically, all stages started out with a light brown, fairly even coloration. Thickness and evenness progressed through the stages with time. Evenness was more apparent on stages one and two. Once the growth was established, the thickness of the biogrowth increased rapidly on stages one and two and progressively more slowly through stages three and four. As the thickness increased, the biogrowth became darker in color and fibrous in texture. Growth in stages three and four was frequently nodular in character under low loading conditions. This was especially apparent in the lagplant throughout the entire study. The lagplant discs seldom showed complete coverage in stages three and four. Under heavy loading conditions the biogrowth in the polyplants frequently had smooth, even characteristics in all stages.

Although slight variations were noted in the polyplants with each waste type, colors typically varied over a two- to three-week period from light brown to dark brown to blue-gray to almost black. The darkest color was normally representative of the thickest or heaviest biogrowth. During corn canning the biogrowth colors were typically milky brown. Orange predominated during the pumpkin season. The biogrowth coloration associated with the lagplant did not change with waste types and was generally darker than polyplant color.

Although some degree of sloughing undoubtedly occurred continuously, the rate increased as the biogrowth became heavier and darker. In the dark growth stages, sloughing became very heavy with the majority of biomass frequently being lost over a two- to four-day period. This phenomenon may be analogous to the "unloading" frequently observed in trickling filters. Normally, isolated patches of heavy biogrowth remained upon the disc surface after unloading was complete. The bare areas among the patches of biogrowth often required one to two weeks under light loading conditions to become covered again with the light brown substance that typified initial stages of biogrowth. Following heavy loading conditions regrowth was fast with dramatic increases in biogrowth frequently occurring in 24 to 48 hours.

The third stage normally appeared to carry a greater biomass inventory than the fourth stage. However, the complete, uniform coverages of the discs by heavy biomass characteristics of stages one and two was seldom observed in stages three and four under light load conditions.

In stages three and four, a light brown coloration was frequently observed among patches of bluish-gray biogrowth. Sloughing apparently occurred at a rate which permitted only isolated patches of mature biogrowth to develop.

Stages one and two in all units often alternately unloaded their biomass inventories. Thus, when the discs of one stage were observed to contain heavy biogrowth coverage, the other stage frequently exhibited a sparse, patchy growth associated with unloading.

Early in the Phase I study with the discs turning at 4 revolutions per minute, low dissolved oxygen conditions developed concurrently with the development of heavy biogrowth. At this time, the biomass in all stages became very black, and unloading occurred. After the increase of disc speed to 8 revolutions per minute, dissolved oxygen was maintained in all stages and a recurrence of the dark black growth was not observed.

Polyplants

Flow rates to the polyplants were intentionally varied from about 0.4 gallons per day per square foot to 3.7 gallons per day per square foot. However, a variety of wastewater types and many uncontrollable variables were encountered during the study.

Temperature---Raw wastewater temperatures varied from 8 degrees C to 28 degrees C, and averaged about 22 degrees C. RBS treatment generally lowered the wastewater temperature one or two degrees C, although temperature drops of as much as 8 degrees C were observed.

Dissolved Oxygen---Dissolved oxygen (DO) levels in the influent wastewater varied from 0.4 to 5.4 milligrams per liter. At the lower flow rates effluent DO levels were usually 4 to 7 milligrams per liter higher than the influent levels, and at the higher flow rates the effluent DO levels were about 0.5 to 2.0 milligrams per liter higher than the influent levels. In polyplant-2, which was operated under the higher hydraulic loads, the DO levels frequently dropped in going from the second to the third stage and occasionally in going from the first to the second stage. In no case, however, did the DO drop below 0.6 milligrams per liter.

pH---A recording pH meter monitoring the influent to the polyplants revealed wide fluctuations in raw wastewater pH. The lowest pH recorded was 2.5 and the highest was 10.2. Daily variations usually ranged from about 4.0 to 9.0. Throughout most of the 24-hour sampling period the pH was in the range of 4 to 6. The high pH values were experienced over a two to three hour period commencing in the early morning hours - probably the result of wash-down operations following the completion of the second shift of processing.

Biochemical Oxygen Demand---The BOD_5 of the screened Owatonna Canning Company process wastewater ranged from 240 to 1,800 milligrams per liter. After treatment with the four-stage RBS system the effluent BOD_5 varied from 6 to 1,385 milligrams per liter. The large spread in the BOD values represents the variability typically encountered in the food processing industry as the result of product changes and daily water usage fluctuations.

In several of the observations the BOD_5 removal efficiency dropped in going from two stages of treatment to three stages of treatment. This trend was most noticeable in polyplant-2 which was operated at very high flow rates, and it was usually accompanied by a decrease in DO concentrations. This also occurred in other stages, but to a lesser extent.

Average BOD_5 concentrations and BOD_5 removal efficiencies have been calculated based on waste type and flow rate and are presented in Table 1. This analysis is rather general but does serve to point out some trends. The most obvious trend is that of higher BOD_5 removal efficiencies for the lower flow rates for any given waste type. Also noticeable is the dependence of BOD_5 removal on waste type. For example, when comparing the BOD_5 removal efficiencies at a flow rate of 288 gallons per day for the different wast types, the highest efficiencies were obtained when treating the corn-green bean wastewater with lower efficiencies for the beef stew-corn-green bean waste and the beef stew-corn waste. At the higher rates of flow these trends became less apparent because of the decreasing consistency of performance. Since beef stew-corn wastewater was treated first, followed by a combination beef stew-corn-green bean wastewater and then corn-green bean wastewater, the higher removal efficiencies for the corn-green bean wastewater may have resulted from biomass acclimation to the high-strength corn wastewater.

Figures 3 through 6 present the relationships between BOD_5 removal efficiency and organic loading expressed in terms of pounds of BOD_5 applied per day per 1,000 square feet for one, two, three, and four stages of treatment during Phase II of the study. The relationships have been approximated by fitting regression lines to the data with no distinction being made for waste type. However, in Figures 3 through 6 the different waste types have been indicated through the use of various symbols. It should be noted that the data were obtained from two pilot units operating in parallel and that most of the data at the low loadings came from one unit while the data for the higher loadings came from the other unit. Although the changes in performance could be due to some unknown difference between units, it was assumed that the two units would perform similarly under identical conditions and that the differences in performance were related to loading rates, either hydraulic and/or organic.

Figures 7 through 10 present the results of BOD_5 removal efficiency as a function of hydraulic loading expressed as gallons per day per square foot for one, two, three and four stages during Phase II of the study. The surface area considered in calculating the hydraulic loading is taken as the total surface area of the number of stages being evaluated for a given graph. Thus, for any given flow rate, as the number of stages increases, the hydraulic loading decreases.

Table 1. BOD DATA AVERAGES FOR POLYPLANTS WITH RESPECT TO WASTE TYPE AND FLOW

	PHASE I		PHASE II									
Waste type	B	B,A	B,C	B,C	B,C,GB	B,C,GB	C,GB	C,GB	C,GB	C,GB	B	B
Flow to plant(gal/day)	366	381	288	2880	288	2880	288	715	1400	2880	680	1420
No. of observations	12	13	3	3	6	6	4	2	2	4	12	12
Polyplant no.	1	1	1	2	1	2	1	1	2	2	1	2
Average BOD (mg/l)												
Influent	992	534	957	1187	852	1225	1146	1128	1112	1109	735	715
First-stage effluent	486	198	785	992	593	1263	691	705	940	1002	477	562
Second-stage effluent	321	116	690	808	426	1092	321	582	852	935	448	474
Third-stage effluent	275	74	552	998	199	1038	114	548	798	912	265	423
Fourth-stage effluent	192	43	392	760	154	1036	71	375	708	862	174	378
Average of percent BOD removal observations												
One-stage	51.0	62.9	23.0	20.2	29.9	-4.9	39.4	37.7	14.7	9.5	33.7	20.7
Two-stages	67.6	78.3	34.9	37.6	52.5	10.4	72.1	48.1	21.8	15.0	43.0	33.8
Three-stages	72.3	86.1	46.1	17.6	76.0	13.8	90.2	51.0	27.4	17.2	64.6	41.1
Four-stages	80.6	91.9	63.8	44.3	80.9	14.5	93.8	66.8	35.3	21.8	77.2	47.7

NOTE: A = asparagus, B = beef stew, C = corn, GB = green beans, P = pumpkin

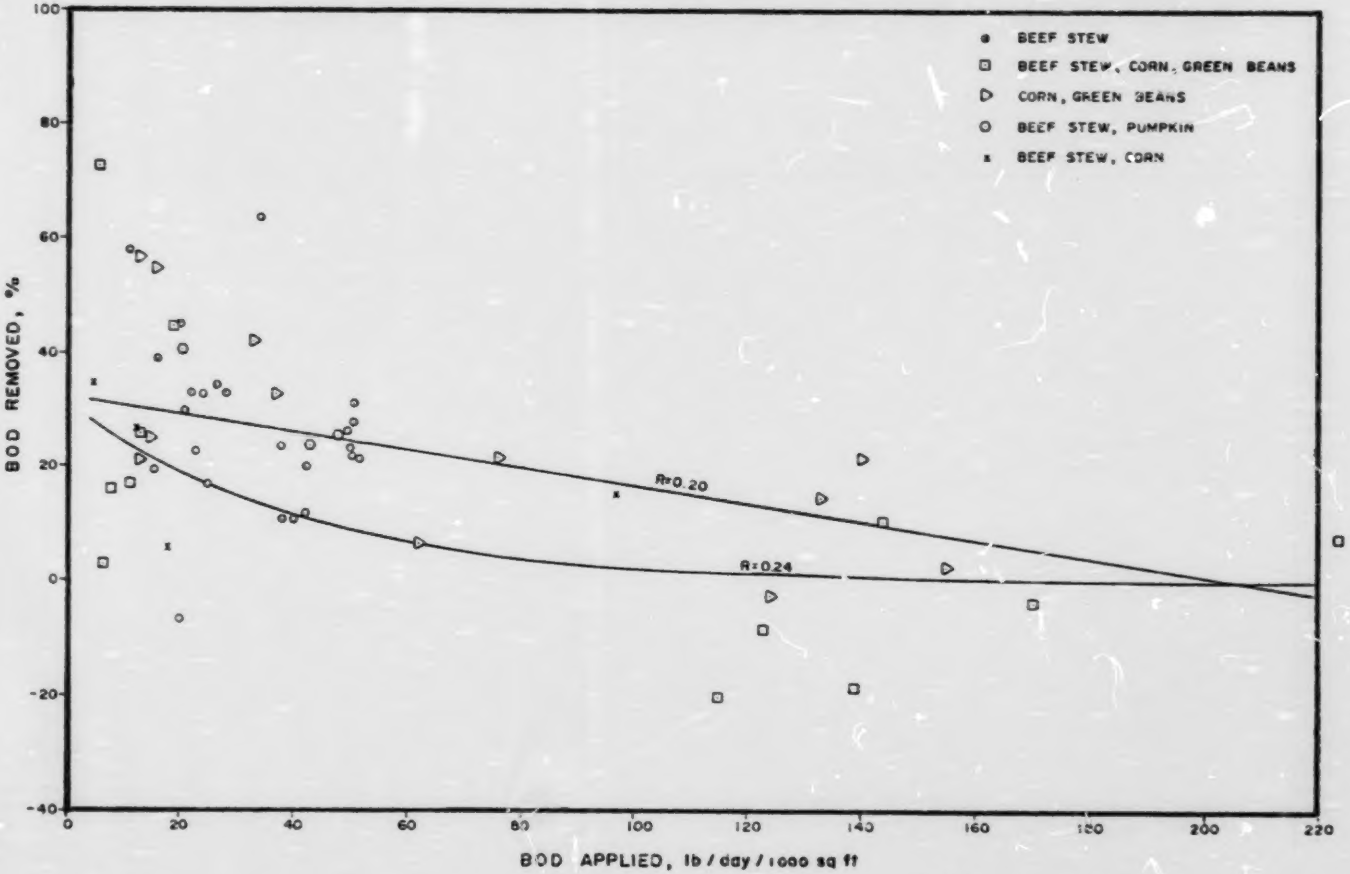

Figure 3. One-stage organic load - BOD removal observations for polyplants during RBS treatment of canning process wastewater at Owatonna Canning Company.

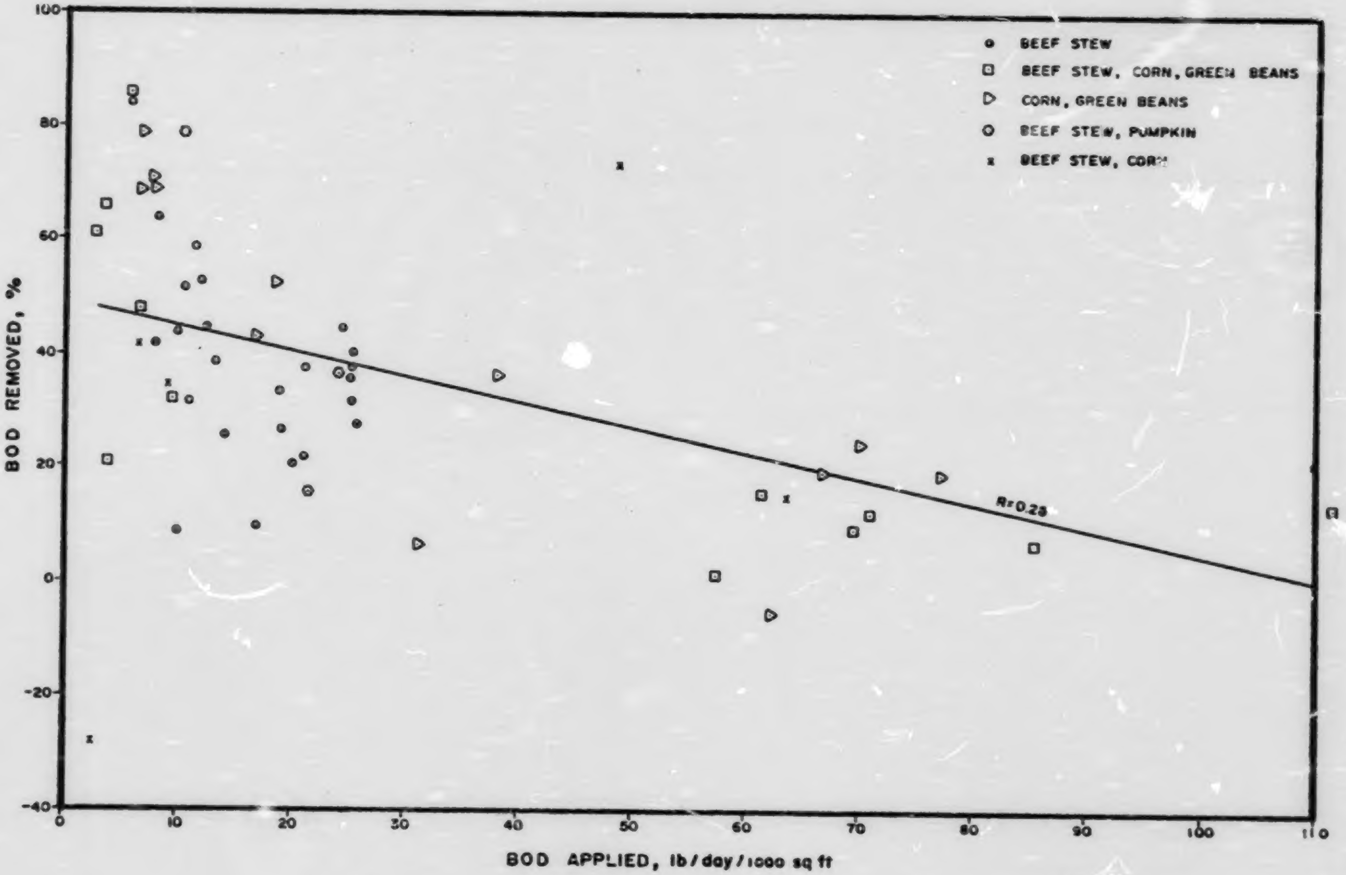

Figure 4. Two-stage organic load - BOD removal observations for polyplants during RBS treatment of canning process wastewater at Owatonna Canning Company.

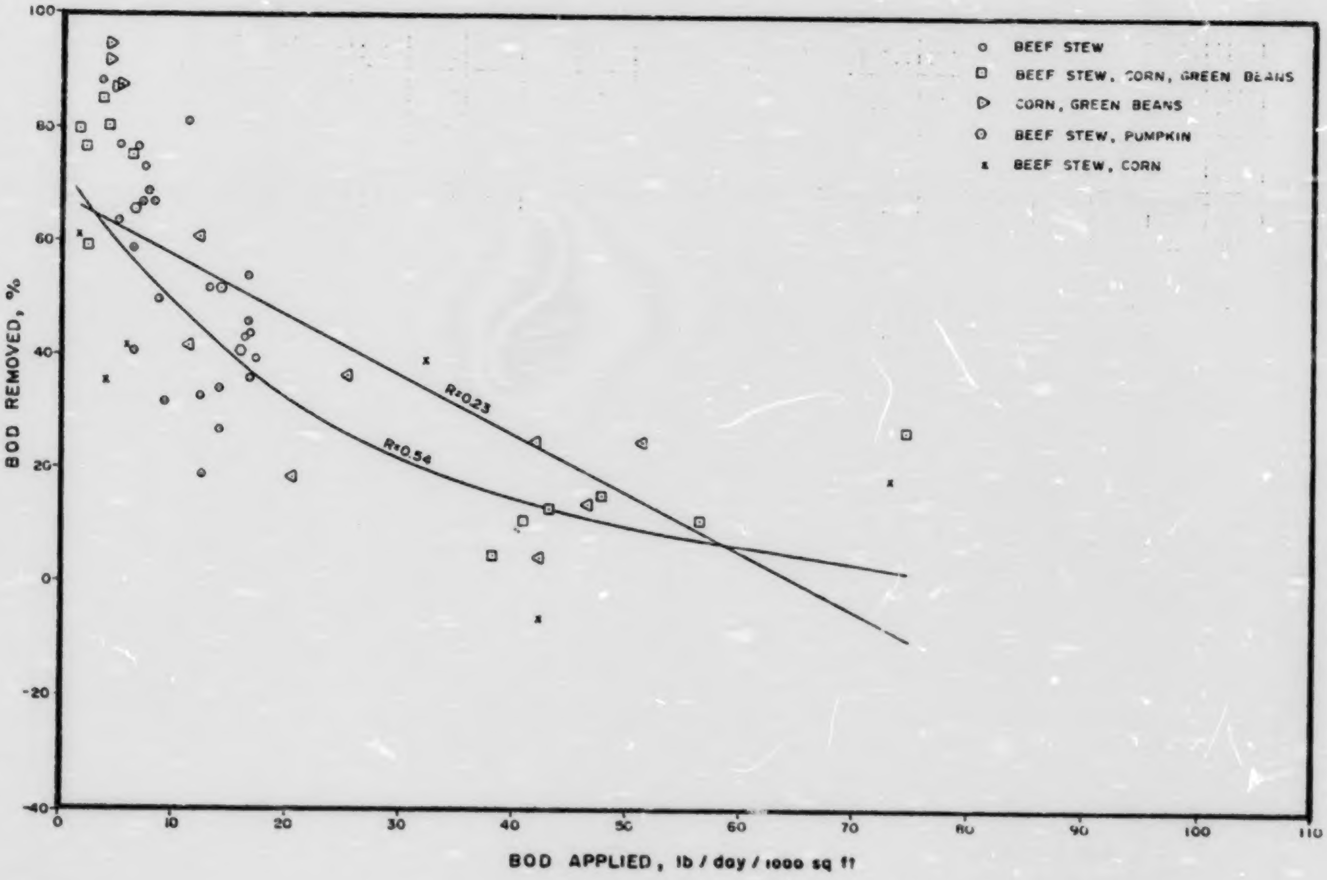

Figure 5. Three-stage organic load - BOD removal observations for polyplants during RBS treatment of canning process wastewater at Owatonna Canning Company.

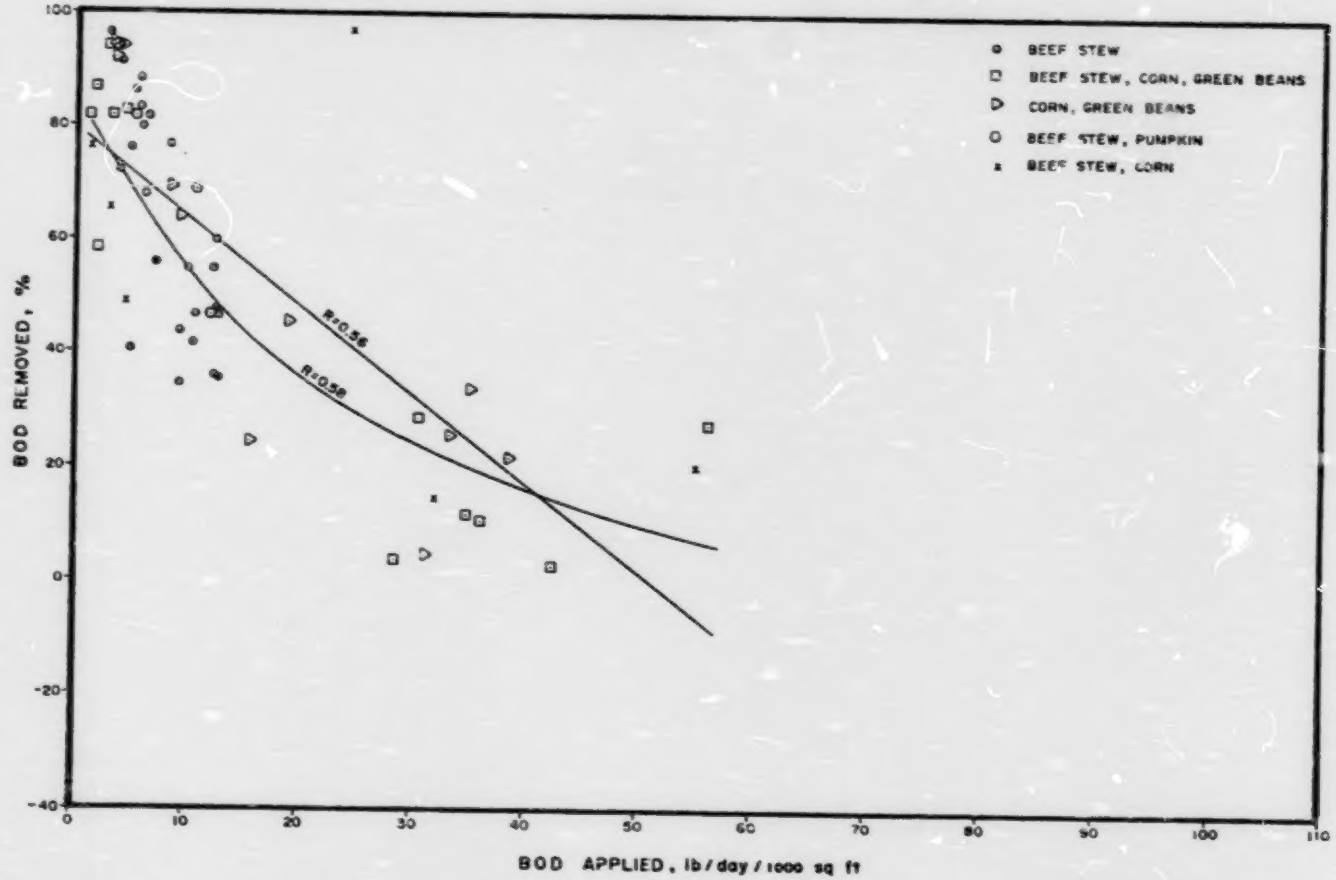

Figure 6. Four-stage organic load - BOD removal observations for polyplants during RBS treatment of canning process wastewater at Owatonna Canning Company.

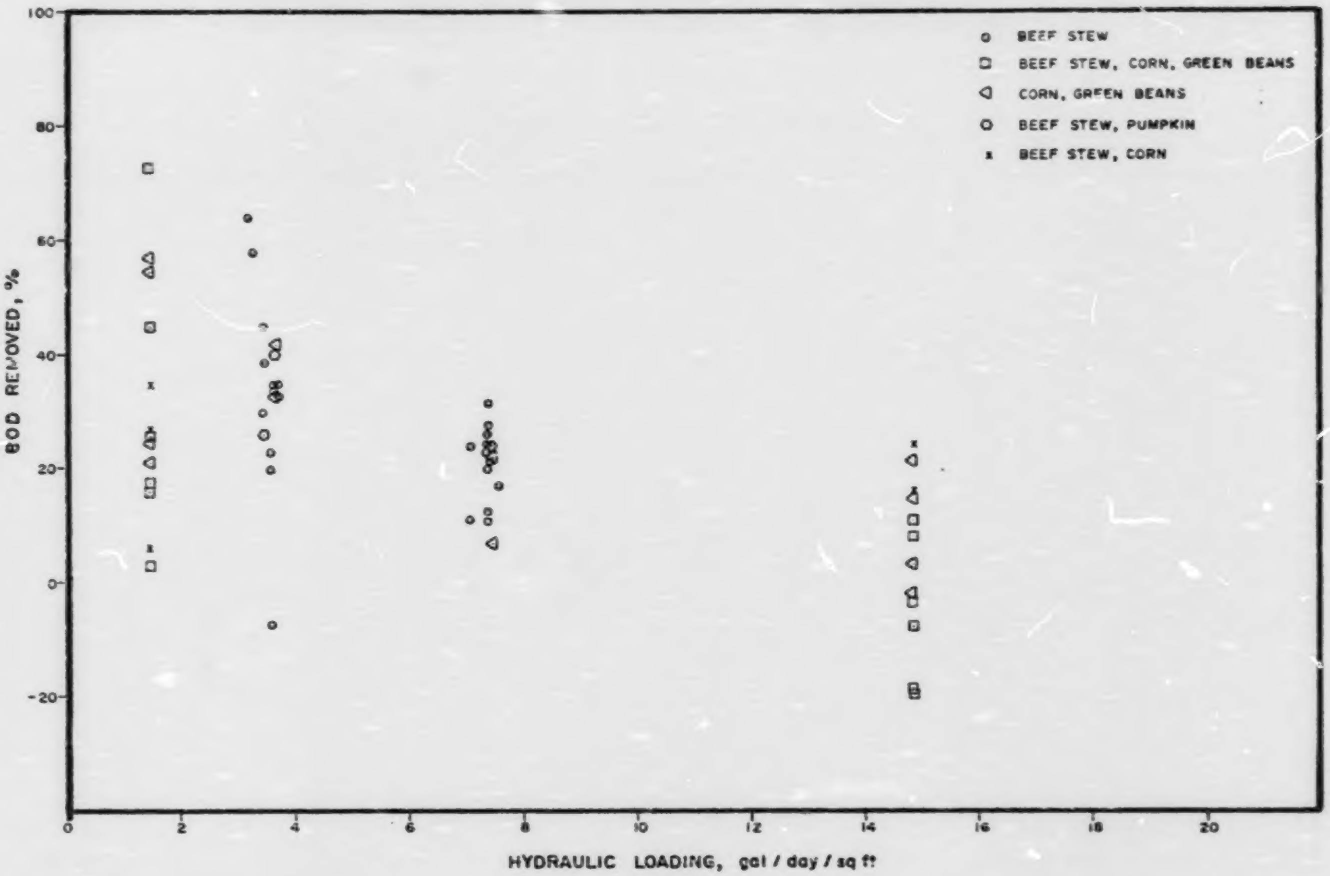

Figure 7. One-stage hydraulic load - BOD removal observations for polyplants during RBS treatment of canning process wastewater at Owatonna Canning Company.

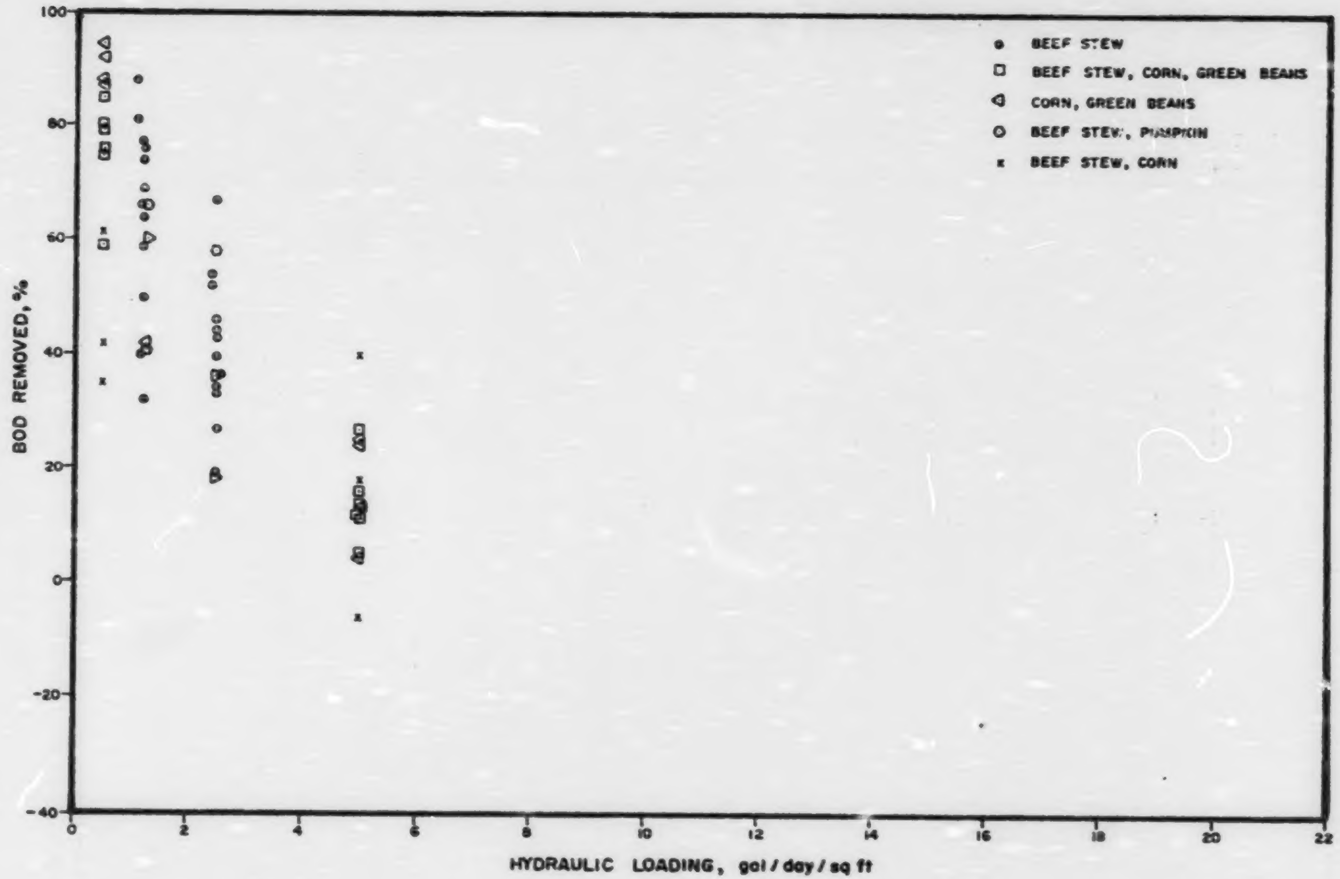

Figure 9. Three-stage hydraulic load - BOD removal observations for polyplants during RBS treatment of canning process wastewater at Owatonna Canning Company.

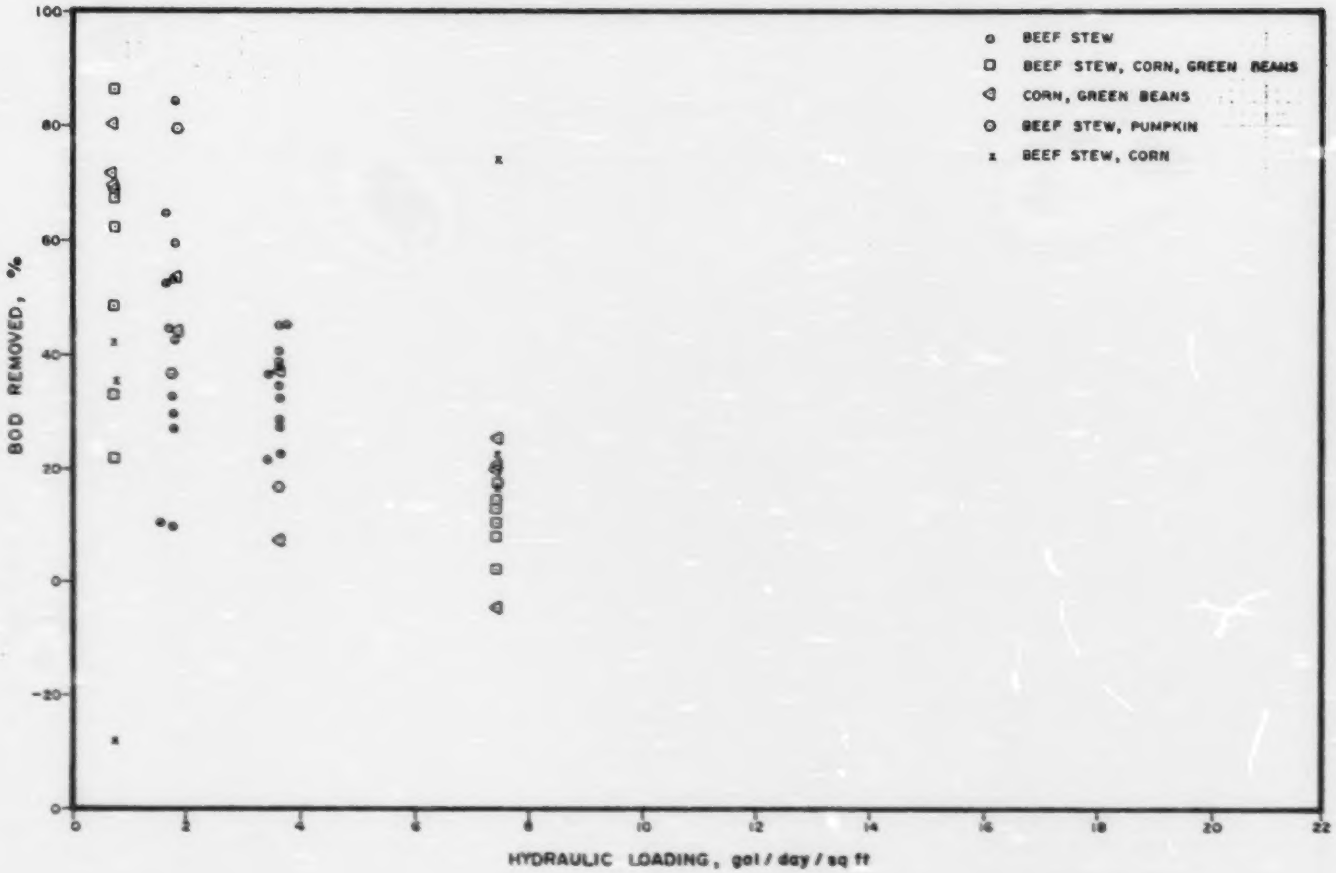

Figure 8. Two-stage hydraulic load - BOD removal observations for polyplants during RBS treatment of canning process wastewater at Owatonna Canning Company.

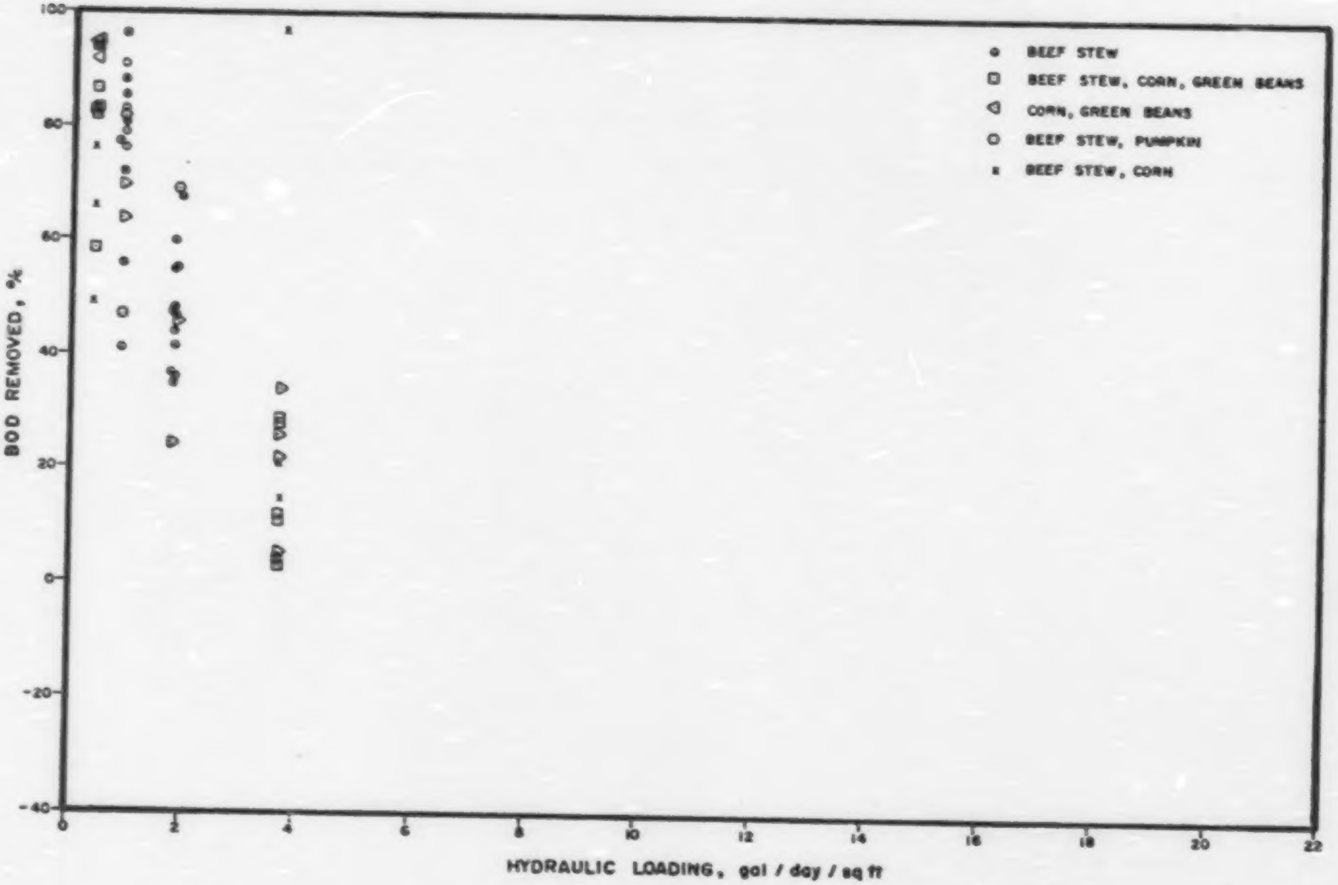

Figure 10. Four-stage hydraulic load - BOD removal observations for polyplants during RBS treatment of canning process wastewater at Owatonna Canning Company.

The Phase II study differed from Phase I in that the flow rate was purposely varied in Phase II in order to assess the effect of flow rate on performance. Unfortunately, an in-depth analysis of performance versus hydraulic loading was not possible since the type of waste changes frequently throughout the study. However, Figures 7 through 10 illustrate the definite existence of a trend toward increasing BOD_5 removal efficiencies at lower hydraulic loadings for all numbers of stages of treatment and greater consistency of performance with increasing stages of treatment.

For most of the waste streams the data available are for a low flow rate and a very high flow rate. However, data for the corn-green bean wastewater are available for four different flow rates. This specific data lends itself well to an analysis of BOD_5 removal efficiency versus flow rate (or hydraulic loading). Figure 11 presents the relationship between average BOD_5 removals versus flow rate applied to the pilot unit with a family of curves accounting for different numbers of stages of treatment. The data plotted in Figure 11 were excerpted from Table 1 and the curves shown are simple "visual best-fit" approximations.

The curves in Figure 11 indicate several things: (1) BOD_5 removal performance was very much a function of flow rate, with best removals realized at lower flows, (2) increasing the number of stages of treatment (thus reducing hydraulic loading) improved the BOD_5 removal at all flow rates, and (3) the effect on percent removal of providing additional surface area was largest at low to medium flow rates.

In Figure 12 the average BOD_5 removal performance during Phase II of the study is plotted as a function of hydraulic loading in terms of gallons per day per square foot for all waste streams taken compositely. In addition, as an indication of data spread, one standard deviation has been plotted on each side of the mean value for each set of data. (With a normal distribution of the data, approximately 68 percent of the data points would fall within one standard deviation on either side of the mean.)

Biological treatment processes are usually considered to exhibit kinetics typical of first or higher order reactions with respect to carbonaceous BOD removal. It is known that for reactions of first order or higher, better performance is obtained when the flow regime through the reactor is plug-flow rather than completely-mixed, all other conditions being equal. One method of approximating plug-flow conditions is to have a series or staged reactor consisting of several completely-mixed compartments, with plug-flow conditions being more closely approximated by increasing the number of stages.

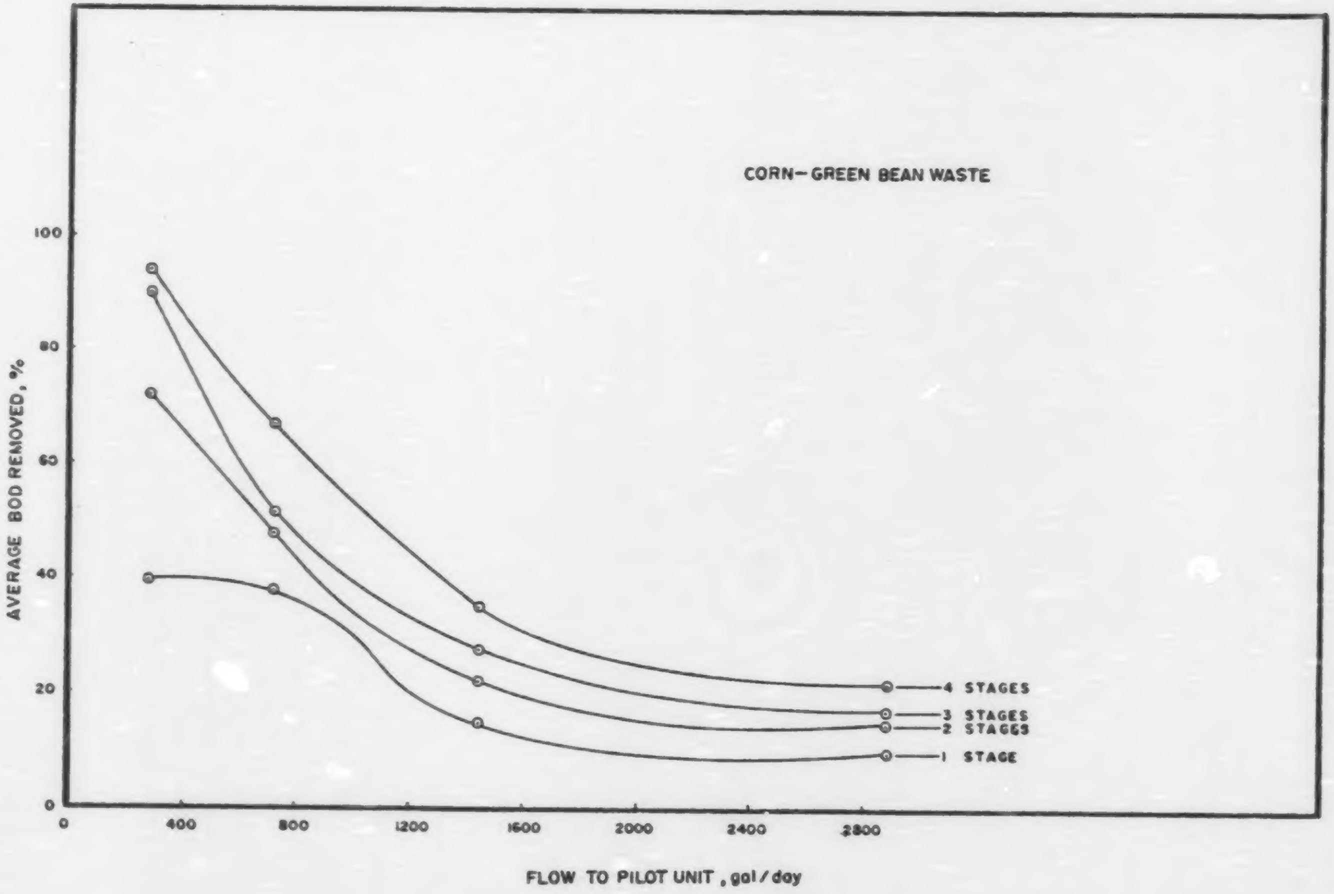

Figure 11. Flow - BOD removal observation averages for polyplants during RBS treatment of corn-green bean process wastewater at Owatonna Canning Company.

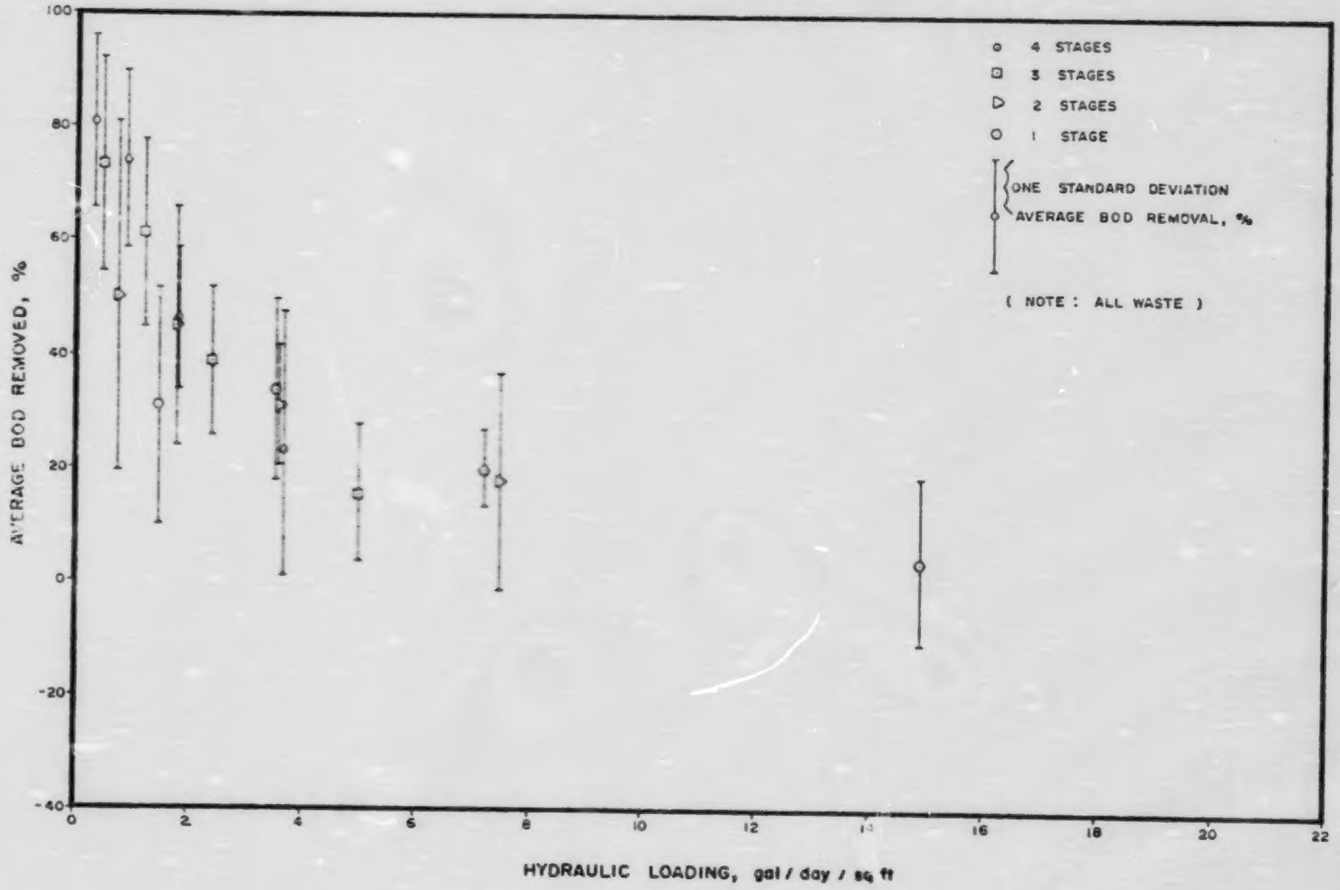

Figure 12. Composite of hydraulic load - BOD removal observation averages for polyplants during RBS treatment of canning process wastewater at Owatonna Canning Company.

Therefore, considering the "staged" design of the RBS pilot units used in this study, one would expect to obtain better BOD removals as the number of stages of treatment increases, all other conditions being equal. The data for a given flow rate cannot be compared since the results obtained when using more stages of treatment acutally reflect the improved performance due to increasing the surface area and decreasing the surface loading. It becomes necessary then to make the analysis for similar total hydraulic surface loading rates (with the assumption that equal hydraulic surface loading rates result in equal contact times between substrate and biomass).

The effect of staging can be examined by referring to Figure 12. For example, considering the third and fourth points left of the ordinate, it is seen that the fourth data point representing four stages of treatment indicates better BOD_5 removal than the third data point which represents two stages of treatment even though the hydraulic loading in the four-stage case is slightly higher. This type of relationship existed for several other points, and was perhaps the result of staging. However, the fact that the type of wastewater being treated was not constant complicates this argument. For the points falling near 3.6 gallons per day per square foot, for example, better performance was obtained from fewer stages of treatment - completely contradicting logical expectations. Here again, however, waste type may have been the dominating factor. At any rate, it should be stated that although these pilot study results do not prove the benefits of staging, such benefits should nevertheless be anticipated.

Solids---A great deal of difficulty was experienced in the laboratory settling of the effluent samples from each stage of treatment in the Phase II study. For example, the effluent from a particular stage might settle fairly well while the effluent from the following stage might settle very poorly. Also, the Imhoff cones would sometimes develop a zone of clarified liquid between layers of solids-laden liquid. In any case, it appears that the settling of stage effluents (and thus the solids data and other performance data) were sometimes inconsistent because of this laboratory problem.

A comparison of the ratio of total volatile solids to total solids showed that the proportion of volatile solids decreased with additional treatment. This indicates that as the waste was subjected to RBS treatment, the solids were more highly stabilized with each additional stage of treatment. Also, at the higher flow rates the proportion of volatile solids was greater than at lower flow rates, indicating that there was less stabilization of solids at higher flow rates.

The suspended solids data (obtained by analyzing the laboratory settled effluent of each stage) indicated a general trend toward increasing removals with increasing stages of treatment, although most of the suspended solids removal obtained was associated with the first stage of RBS treatment. Best suspended solids removals seemed to occur for the corn-green bean wastewater.

Nitrogen and Phosphorus---Kjeldahl nitrogen, ammonia nitrogen and nitrate nitrogen analyses were made on the influent and on all stage effluents. The majority of the Kjeldahl nitrogen that was removed was apparently associated with the influent settleable solids. Nitrification was not expected, and was not observed during any portion of the study.

Total phosphorus concentrations in the influent wastewater were measured during the study. Limited information was available on phosphorus removals, since effluent phosphorus levels were monitored only during Phase I.

Canning wastewater is often said to be nutrient deficient from a biological treatment viewpoint. It has generally been accepted that a BOD:N:P ratio of 100:5:1 is required for biological treatment. However, the BOD:N ratio was almost always greater than 100:5 (the average value was approximately 100:3), and phosphorus was frequently less than 1 percent of the BOD during the study.

A correlation between low phosphorus and decreased BOD removals was suspected, but the data were too limited to confirm this. In any case, no supplementary nutrients were added to the process wastewater at any time during the study. Additional work would be required to determine if nutrient additions would enhance the RBS performance.

Lagplant

For the Phase II portion of the study, a third RBS pilot unit (designated lagplant) was installed to treat the effluent from an anaerobic lagoon at the Owatonna Canning Company. Operation of the lagplant continued from August 11, 1974 to October 16, 1974. As with the polyplants during Phase II, 24-hour composite samples were collected by Minnesota Valley Testing and were analyzed by Hormel Laboratories. Electrical power to the lagplant was provided by a diesel powered generator located at the lagoon. Because of several power outages that interrupted operation of the lagplant for periods up to several days in length, some of the original data observation sets have been discarded.

Flow to the lagplant was maintained at 288 gallons per day until September 17, when it was increased to approximately 715 gallons per day. Four-stage surface loading rates resulting from these flow rates were 0.37 and 0.93 gallons per day per square foot.

Temperature---Influent wastewater temperatures ranged from 10 degrees C to 27 degrees C, with temperatures being noticeably lower after the middle of September. Influent temperatures averaged 22.8 degrees C during the period of August 11 to September 16 and 14.8 degrees C from September 17 to October 17. Effluent temperatures fluctuated above and below the influent temperatures but usually by no more than 1 degree C to 2 degrees C.

Dissolved Oxygen---Dissolved oxygen concentrations in the lagplant influent ranged from 0.6 to 7.7 milligrams per liter with 1 to 2 milligrams per liter being most typical. Effluent DO levels were usually 3 to 7 milligrams per liter higher than influent DO levels. At the flow rate of 715 gallons per day the DO concentration frequently dropped in the second stage, usually by 0.5 to 1.0 milligrams per liter.

pH---No pH data were available for the lagplant pilot unit.

Biochemical Oxygen Demand---Total BOD_5 concentrations in the lagplant influent ranged from 340 to 1,180 milligrams per liter. Day-to-day fluctuations in BOD_5 concentrations were lessened by the equalization effect of the lagoon; however, there was a general tendency toward gradually increasing and the decreasing BOD_5 concentrations. The peak BOD_5 occurred near the middle of the study and was undoubtedly the result of corn and green bean processing.

Data collected on September 17 and 18 show a significant decline in performance when the flow rate was increased followed by recovery to a performance level somewhat lower than for the preceding lower flow rate.

BOD_5 removal efficiency data as a function of surface hydraulic loading rates for one, two, three and four stages are summarized in Figure 13, in which average BOD_5 removal efficiency is plotted with hydraulic loading rate to show that BOD_5 removal decreases with increasing hydraulic surface loading rates.

As in the case of BOD_5 removal, the COD data indicated (1) better performance at low organic loadings, (2) better performance at low hydraulic loadings, and (3) somewhat more consistent results with higher number of stages of treatment.

Solids---The concentration of suspended solids in the settled effluent from each stage was roughly the same as for the polyplants. The percent removal of suspended solids in the lagplant was less than for the polyplants, possibly because the lagplant influent suspended solids concentrations were lower.

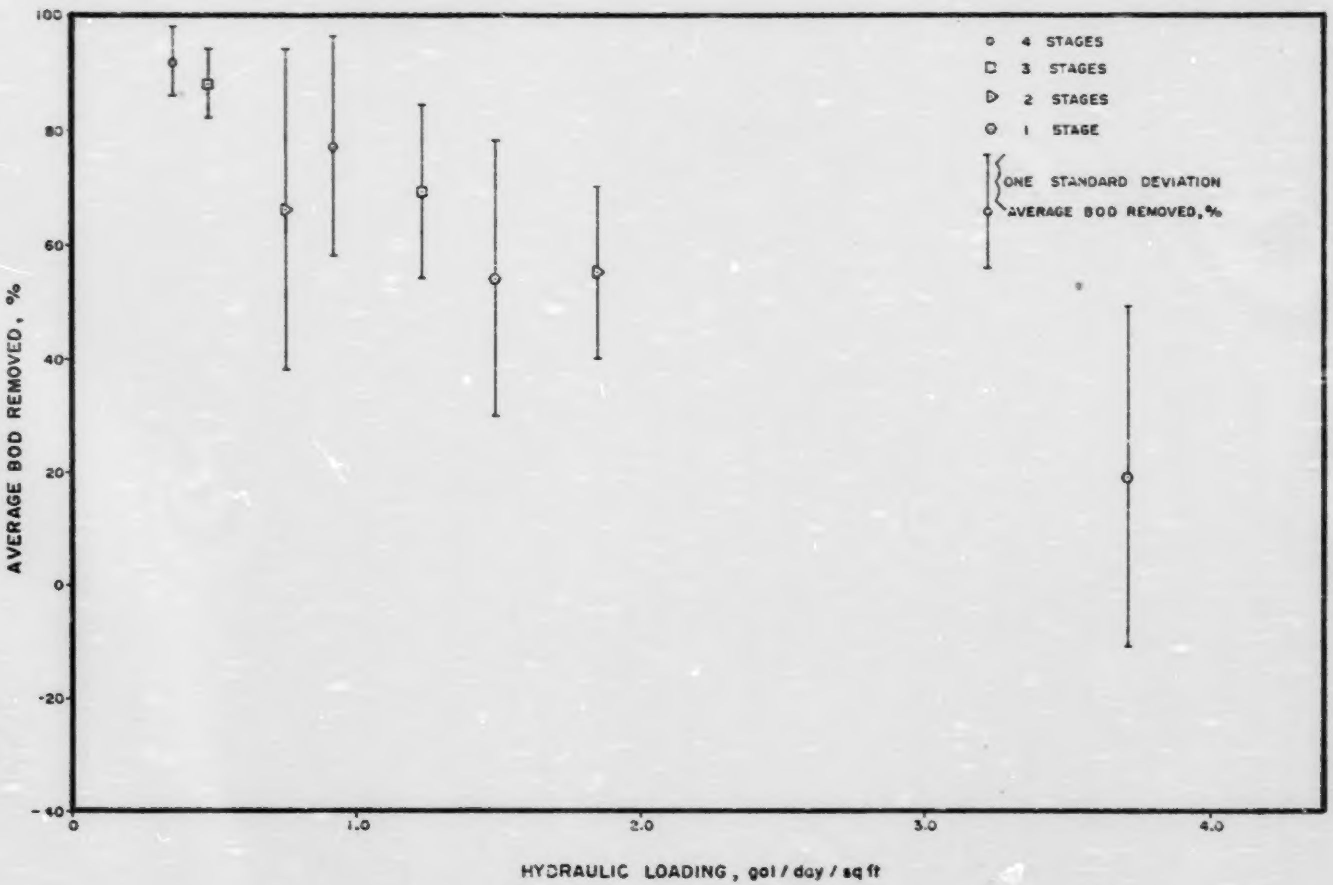

Figure 13. Composite of hydraulic load - BOD removal ovservation averages for the lagplant during RBS treatment of anaerobic lagoon effluent at Owatonna Canning Company.

Settleable solids data were variable from day to day and from stage to stage, but the existence of trends was not evident.

Total solids and total volatile solids data show increasing percent removal with each additional stage and better removals at the lower flow rate. The proportion of total volatile solids to total solids decreased for each additional stage of treatment.

Nitrogen and Phosphorus---Removal of Kjeldahl nitrogen in the lagplant was similar to the removal in the polyplants. Ammonia nitrogen was reported in 14 of the 21 influent samples, but no ammonia was present in the fourth stage. Ammonia nitrogen may have been converted to nitrates by nitrifying organisms, although the nitrate nitrogen data did not confirm this. Nitrate nitrogen data show a few isolated occurrences of nitrates but, generally, there was no nitrate nitrogen present in the treated wastewater.

The average BOD:N:P value was approximately 100:4.8:1.8.

SUMMARY

Although the RBS system is a proven biological wastewater treatment process in Europe, its capabilities have not been widely demonstrated and accepted to date in America. Treatment of canning company process wastewater has been and continues to be a difficult problem for the food industry. The combination of these factors led to a one-season RBS pilot plant study in Owatonna Canning Company in Owatonna, Minnesota.

Data collected during the study illustrate some of the parameters which influenct the performance of the RBS process. The RBS process was shown to be capable of treating wastewater under difficult and variable loading conditions typical of food processing facilities.

Throughout the study, no attempts were made to control or modify the variability of the process wastewater being treated. Although one loses control of many critical variables with this approach, such studies are an essential link between theory and practice. As a result of this study, the RBS system seems to be worthy of consideration when selecting a system to treat vegetable canning wastewater.

A PRELIMINARY REPORT ON STUDIES TO DEVELOP ALTERNATIVE METHODS OF REMOVING POLLUTANTS FROM TUNA (ALBACORE) PROCESS WASTEWATERS*

Harold J. Barnett**
Richard W. Nelson**

INTRODUCTION

Many commercial fish processors foresee difficulties complying with newly promulgated water pollution control laws. Little is known about controlling pollutants in fish processing wastewaters, and considerable time and money have been invested by various governmental agencies and the industry to determine feasible waste treatment methods.[1,2,3,4] Although some expertise has been developed, many problems remain to be solved. In general, recommended treatment systems require considerable land space which is seldom available to fish processing plants built over water, or they require large and complex biological, chemical, and mechanical systems that have not proven entirely satisfactory in pilot or full-scale operations. Thus, the United States commercial fishing industry finds itself in a potentially serious economic position as it attempts to meet effluent guidelines with waste treatment methods that have proven costly or are ill-defined.[5] As a result, there is a need for continued research to develop more effective and economic methods for treating fish processing wastes.

For the past several years the Pacific Utilization Research Center, National Marine Fisheries Service, has been involved at its main laboratory in Seattle and its field laboratory in Kodiak, Alaska, on the characteristics and control of pollution from seafood plant effluents. Currently a pilot-scale waste treatment system that uses a relatively inexpensive modified air flotation and double screening technique is being evaluated in cooperation with Northwest seafood processors. As designed, the pilot plant permits researchers to determine various treatment operations on a systematic basis. That is, evaluations can be made on the basis of coarse and fine screening, or dual screening in combination with air flotation with or without the use of chemicals. The unit is conveniently mobile and flexible as to arrangement and has been used successfully in making pollution abatement studies in shrimp and salmon canneries in the Pacific Northwest. At present, the modified air flotation system is being evaluated in cooperation with a Northwest seafood cannery as a method for treating tuna processing waste effluents. The cannery operation is typical of the industry and includes thawing, butchering, steam pre-cook, loin preparation, can filling, and retorting. The waste streams are combined in a central collection sump used as the source of wastewaters for these studies. Although the work is not completed, preliminary data show promise.

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*Use of names does not imply endorsement but are used to facilitate description.

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METHODS

Modified Air Flotation Equipment

Basic equipment making up the pilot plant are an 18-inch tangential screen Bauer Hydrasieve (Figure 1), a 12-inch Sweco centrifugal wastewater concentrator (CWC) (Figure 2), and a custom-made flotation cell with a variable speed drive sludge removal system (Figure 3). The flotation is equipped with a removal baffle that is used to help promote flotation of solids. A portable air compressor is used to generate dispersed air. Fine air bubbles are produced either by an aeration device made of multiporous tubing or by adding compressed air directly into the intake hose carrying screened effluent to the CWC. Assorted variable-speed materials handling pumps and a holding tank complete the major equipment needed to operate the pilot unit. Assembled for use, the equipment appears in the configuration shown in Figure 4.

Chemicals

Chemicals used in these experiments were selected on the basis of results reported in the literature as well as our own laboratory scale jar tests. Although not exhaustive, these tests determined that for the purpose of coagulation and pH control alum, $Al_2(SO_4)_3$ and lime, $Ca(OH)_2$, were most effective. The use of polymers was also investigated as a potential flocculent to enhance removal of solids from the flotation cell. Based on limited tests, a Betz anionic 1120 polymer was selected for use in these experiments. Automatic feed pumps are used to mix the chemicals with the effluents.

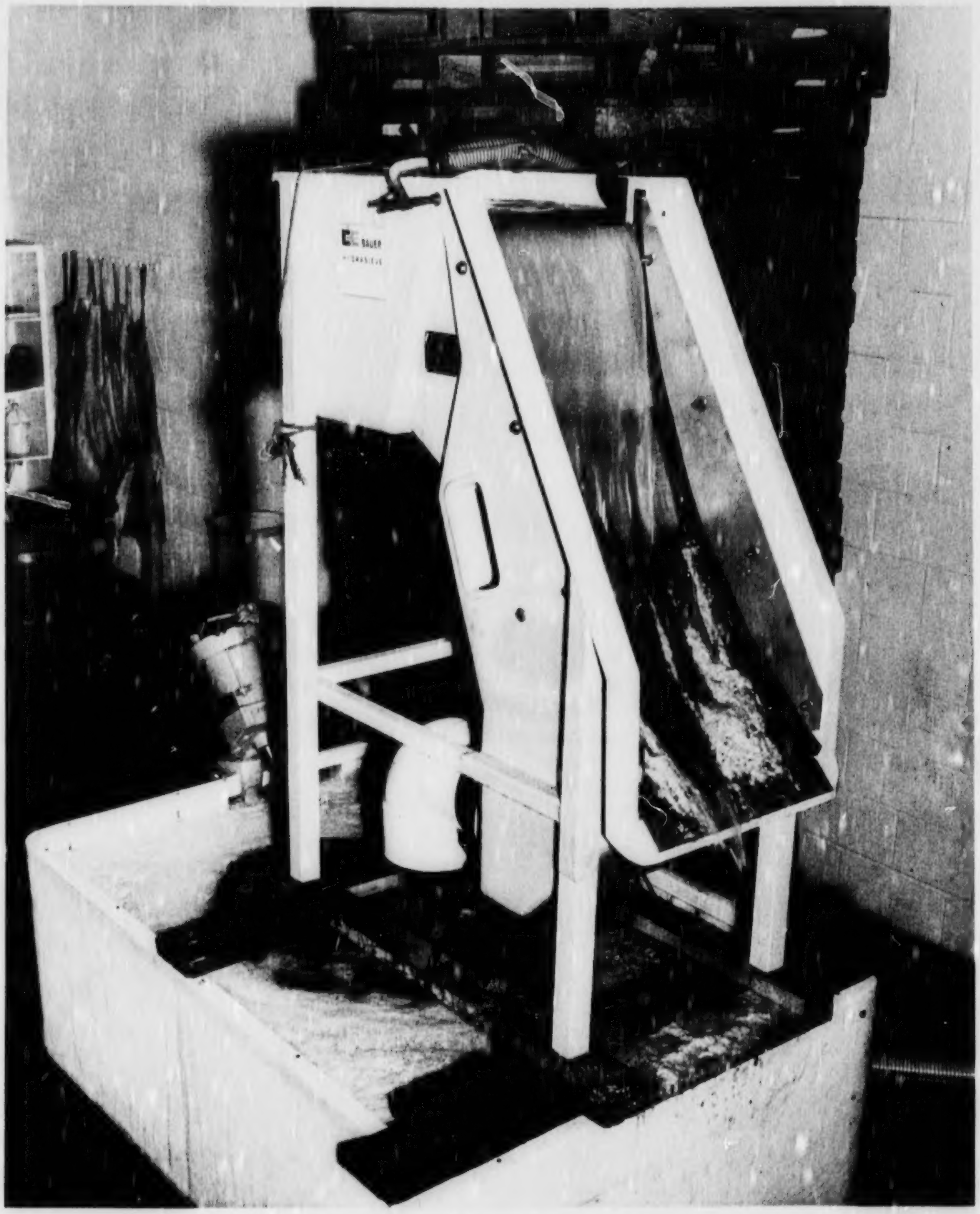
BAUER
HYDRASIEVE

Figure 1. Bauer hydrasieve.

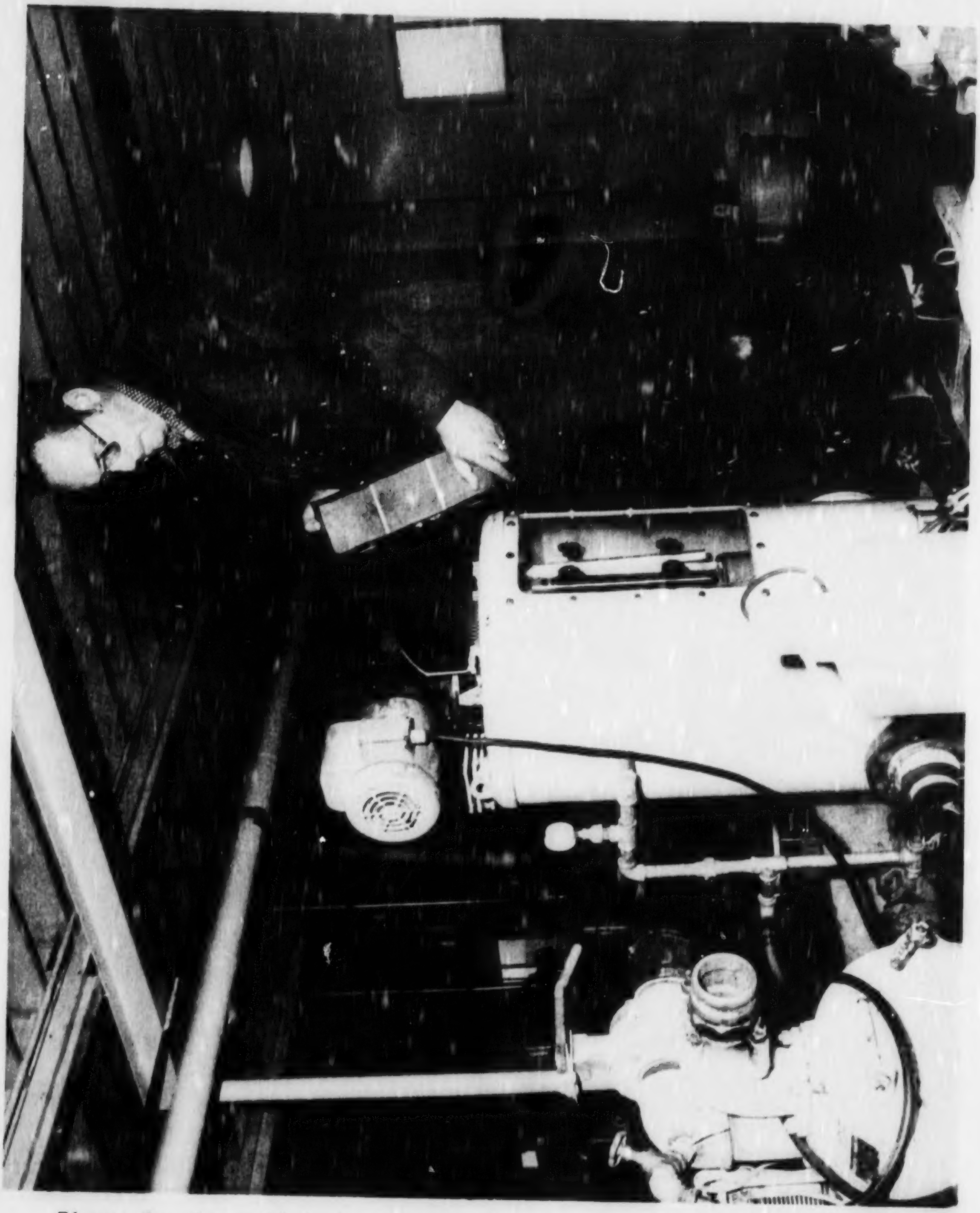

Figure 2. Sweco 12-inch centrifugal wastewater concentrator and one of eight 165-mesh stainless steel screens removed for inspection.

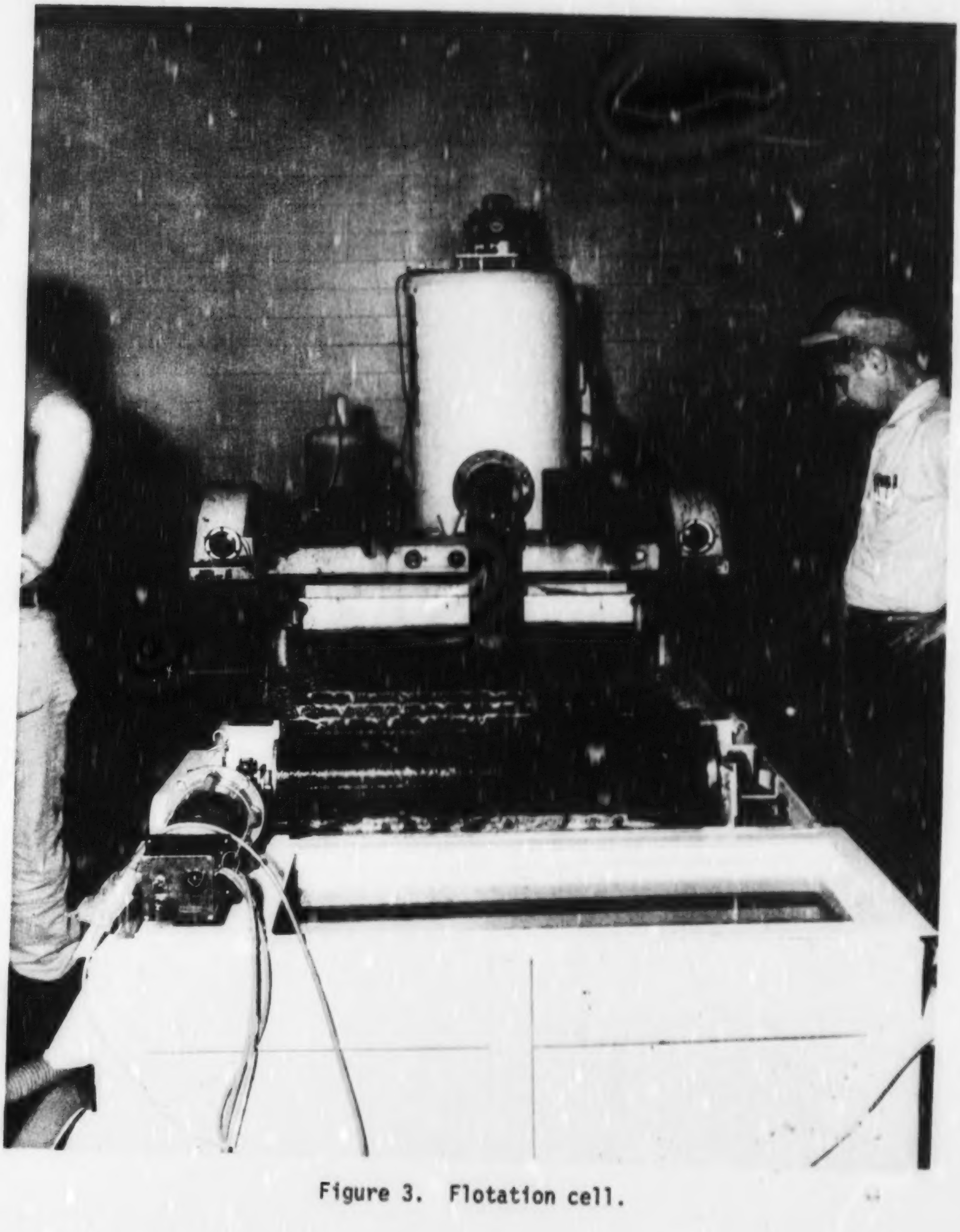

Figure 3. Flotation cell.

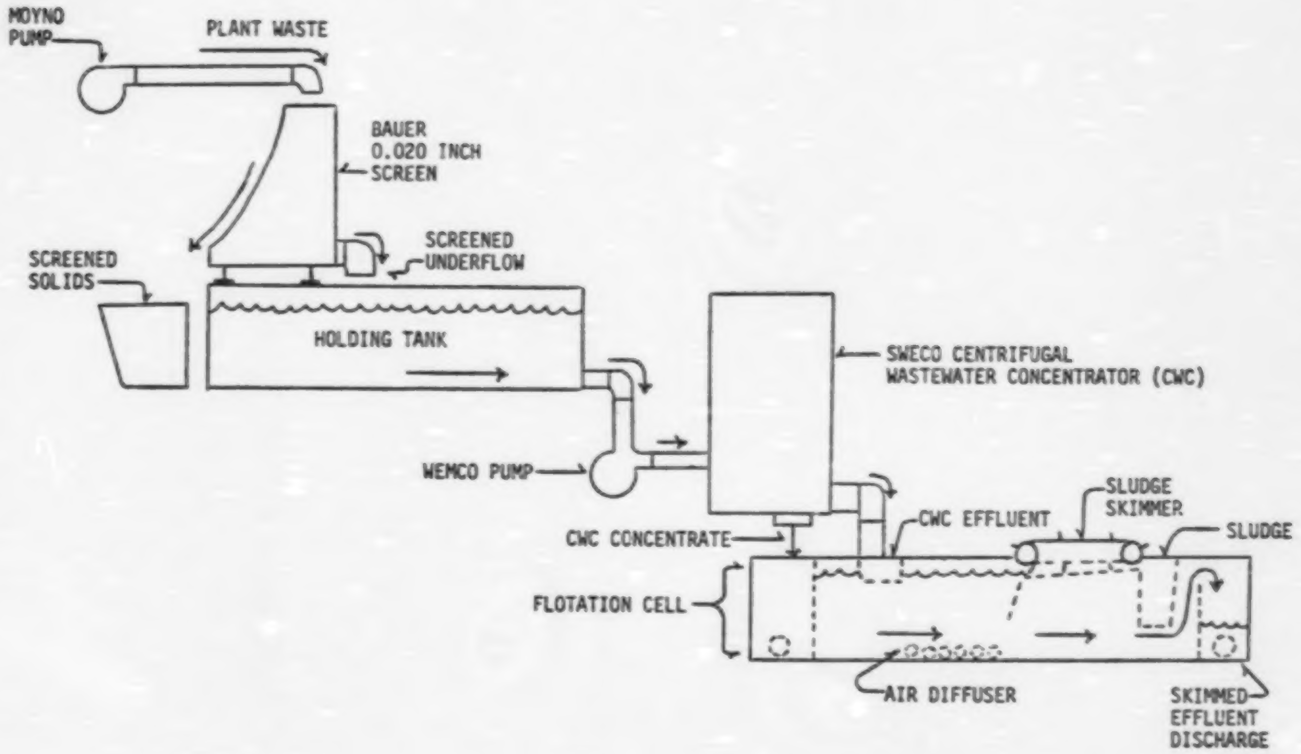
MOYNO PUMP
PLANT WASTE
BAUER 0.020 INCH SCREEN
SCREENED UNDERFLOW
SCREENED SOLIDS
HOLDING TANK
SWECO CENTRIFUGAL WASTEWATER CONCENTRATOR (CWC)
WEMCO PUMP
CWC EFFLUENT
SLUDGE SKIMMER
SLUDGE
CWC CONCENTRATE
FLOTATION CELL
AIR DIFFUSER
SKIMMED EFFLUENT DISCHARGE

Figure 4. Basic pilot plant equipment used in tests to remove solid wastes from tuna cannery effluent.

Flow Measurements

Flow rates related to the operation of the pilot plant were determined by precalibrating variable speed drive pumps with known volume containers and stop watch. Processing wastewaters discharged from the plant were measured with a 1.5 foot model H-flume and an Environmental Measurement Systems ultrasonic flow measuring device.[6] The H-flume was selected because it is portable, relatively compact, and has a rather wide flow rate capacity ranging from 0 to about 1,500 gallons per minute. The metering device was used because of its portability, non-contact (not submerged) operation, and is remote or line operated.

EXPERIMENTAL PROCEDURES

A total of six experiments were made in these preliminary studies. Each experiment was divided into three or four unit operations which included coarse and fine screening procedures, and screening operations combined with air flotation and chemical treatment. Samples were taken periodically during the experiments at each treatment step. These were composited and analyzed according to standard procedures.[7,8] The experiments were based on continuous runs lasting from 1 to 4 hours of operation each.

RESULTS AND DISCUSSION

The data in Table 1 show the results of the tests using the modified dispersed air flotation equipment. The values given are averages of replicate analysis. In the first unit treatment tests, plant effluent was screened by the tangential screen (line 2 of Table 1). Significant reductions in the three parameters measured were observed. A 0.010-inch screen (50 mesh equivalent) was used in these tests. The screen was selected on the basis of tests comparing the settleable solids content in the underflow from a 0.020-inch and 0.010-inch screens. The 0.010-inch screen was found to be about 10 percent more efficient than the 0.020-inch screen. No blinding problems were encountered with the finer screen. In the second stage of testing the centrifugal wastewater concentrator was used in combination with the tangential screen. Although the removal of additional suspended solids was observed, (line 3 of Table 1) no significant reductions were achieved in BOD and in oil and grease. Failure to reduce these parameters can be attributed to the fact that a considerable part of the BOD_5 comes from dissolved soilds which cannot be removed by screening. In addition, the warm processing water temperature (70 to 95 degrees F)

Table 1. EFFECT OF SYSTEMATIC SCREENING AND AIR-FLOTATION TREATMENT OF TUNA CANNERY EFFLUENT

Treatment	Parameters						
	pH	TSS, ppm	% red.	BOD_5, ppm	% red.	O&G ppm	% red.
Unscreened effluent	6.2	2,624	-	4,960	-	2,401	-
Hydra.-sieve screened	6.2	1,835	30	2,890	42	1,197	54
Hyd. + CWC screened	6.2	1,060	59	2,625	47	1,036	57
Hyd. + CWC chemical treatment and flotation	8.3	124	95	1,013	80	126	95

partly solubilizes the oils making them also difficult to screen. The CWC was equipped with 165 mesh screens for these studies.

At this point in our studies tests were made to evaluate the combination of double screening and dispersed air flotation without the use of chemical coagulants as a means of further reducing biodegradeables. Results from these tests indicated that the procedures did not appreciably lower the concentration of solids waste more than could be accomplished with the double screening procedure. Because no significant differences were observed, these test results are not included in Table 1. Final treatment procedures included double screening combined with dispersed air flotation and addition of chemicals. Maximum results were achieved using chemical concentrations of 20 parts per million alum and 150 parts per million lime. Clagget and Wong[9] made similar observations in their studies with salmon wastewaters. Polymer was used at a concentration of 5 parts per million. Compressed air was used continuously at a rate of about 2 standard cubic feet per hour (SCFH). Results of these tests are shown in the bottom line of Table 1. In addition to the removal of the parameters given in the table, we also observed significant clarification of the plant effluent by the final treatment step. Reduction in turbidity (Formazin Turbidity Units) were consistently 98 percent. Generally, floc occurs simultaneously as the waste stream enters the flotation cell resulting in a rapid-forming sludge blanket. Formation of the blanket is further facilitated by aeration resulting from centrifugal screening and the addition of dispersed air. No attempt was made in these preliminary tests to handle the cencentrate from the CWC or the sludge removed from the flotation cell. However, the sludge was analyzed and found to have the chemical composition shown in Table 2.

The results presented in this report indicate that the dispersed air flotation technique described has considerable potential for removing pollutants from tuna processing effluents. However, additional research is essential in the following areas to make the system complete: (1) separation (dewatering) of the solids from the sludge and concentrate, (2) finding use for these solids, (3) evaluation of methods such as recycling treated wastewater to decrease use of chemical additives, and (4) evaluation of methods for removing additional dissolved solids from treated flotation effluent.

Before these and similar research approaches could be considered for commercial use, it would also be necessary to design a total system that would handle each step in the operation. A thorough study of the economic feasibility of the final system is necessary.

Table 2. CHEMICAL COMPOSITION OF SLUDGE REMOVED BY DISPERSED-AIR FLOTATION WITH CHEMICAL TREATMENT OF TUNA CANNING EFFLUENT

Constituent	Wet weight, %	Dry weight, %
Moisture	86.3	-
Grease and oil	8.4	61.3
Protein	2.0	14.6
Salts (alum, lime)	3.3	24.1

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EFFLUENT VARIABILITY IN THE MEAT-PACKING AND POULTRY PROCESSING INDUSTRIES

James F. Scaief*

INTRODUCTION

Increased industrialization has resulted in higher waste loadings on receiving bodies of water and has caused regulatory agencies to require increasingly more stringent effluent standards. These standards, in addition to five-day biochemical oxygen demand (BOD_5) and total suspended solids (TSS), include parameters such as ammonia-nitrogen (NH_3-N), oil and grease (O&G), fecal coliform, and pH.

Tables 1 and 2 summarize the guidelines established for the red meat industry and recommended for the poultry processing industry.

For many meat-packing and poultry processing plants to meet these new guidelines, much needs to be accomplished in controlling their effluent variability. As stated by Ford,[1] an inherent variability is attributed to the treatment system, the characteristics of the raw waste load, and geographical and climatological conditions. Therefore, to minimize the variability one needs to take a look at each factor contributing to this variability and determine what control measures are possible. Analyses of in-plant processes will be necessary and in some cases newer processes may have to be introduced. Provisions might be made to minimize storm water runoff entering the system. The existing guidelines and the probable inclusion of nutrients in effluent standards will, in many cases, require the industries to install further treatment beyond existing secondary treatment. If an industry elects to discharge to a municipal system, pretreatment might be required.

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Table 1. RED MEAT EFFLUENT STANDARDS[a]
(kg/kkg LWK)

Plant Subcategory	7/1/77				7/1/83	
	Best Practical Treatment			New Sources	Best Available Treatment	
	BOD_5	TSS	O&G	NH_3-N	BOD_5	TSS
Slaughterhouse						
I. Simple	0.12	0.20	0.06	0.17	0.03	0.05
II. Complex	0.21	0.25	0.08	0.24	0.04	0.07
Packinghouse						
III. Low-Processing	0.17	0.24	0.08	0.24	0.04	0.06
IV. High-Processing	0.31	0.31	0.13	0.13	0.08	0.10

[a] Federal Register, Volume 39, Number 41, February 28, 1974. Maximum average of daily values for a 30 consecutive day period.

Notes: pH limit is 6.0 to 9.0
Fecal coliform maximum limit is 400 mpn/100 ml.
Maximum for any 1 day is 2 times the average.
1983: O&G, maximum = 10 mg/l
NH_3-N maximum = 8 mg/l

Table 2. POULTRY PROCESSING: RECOMMENDED EFFLUENT LIMITATIONS[a]
Average Limitation
(kg/kkg LWK)

Plant Subcategory	7/1/77 Best Practical Treatment			7/1/83 Best Available Treatment		
	BOD_5	TSS	O&G	BOD_5	TSS	O&G
Chickens	0.46	0.62	0.20	0.30	0.34	0.20
Turkey	0.36	0.57	0.14	0.21	0.24	0.14
Fowl	0.61	0.72	0.15	0.23	0.27	0.15
Ducks	0.77	0.90	0.26	0.39	0.46	0.26

[a] EPA Contract Number 68-01-0593

Notes: Fecal coliform maximum limit is 400 mpn/100 ml.
NH_3-N: New Source and 1983 limit is 4 mg/l.
1983: TKN = 4 mg/l
TP = 2 mg/l
NO_3/NO_2-N = 5 mg/l

Through analysis of data from existing outstanding meat packing, slaughtering and poultry processing plants, it is hoped to identify those combinations of in-plant controls and subsequent wastewater treatment processes which are most efficient in meeting discharge regulations.

Primary objectives:

1. Determine in-plant controls which produce least magnitude and variability in treated effluent loads.
2. Determine treatment system or systems used to produce least magnitude and variability in effluent loads.
3. Determine what percentage of time plant discharge meets established effluent limits.
4. Determine causes when limits are exceeded.
5. Determine the level beyond which a treatment plant ceases to provide effective treatment.

Information needed:

Records on:

1. Production
2. Effluent flow
3. Effluent compositions
    a. Untreated
    b. Treated
4. In-plant process description
5. Treatment plant design

RESULTS

Data Search

Data was obtained for this project from individual state pollution control agencies, the United States Department of Agriculture, North Star Research Institute, and private industry in addition to the Environmental Protection Agency.

Initially it was decided that in order to have a meaningful statistical analysis, at least 40 data points for the various wastewater quality parameters would be needed. This alone limited the number of plants for which data would be available.

Due to the lack of a regular reporting system in many states, only those plants that were believed to be producing a poor quality effluent were monitored regularly. This study is concerned with the more exemplary plants, and consequently there is little information available. Originally it was intended to evaluate the treatment systems with respect to biochemical oxygen demand, chemical oxygen demand, suspended solids, oil and grease, ammonia nitrogen, and phosphorus. It was found that data on parameters other than BOD_5 and SS was very limited, and as a result, comparison of the different types of treatment systems with respect to the other parameters was not possible.

Meat: Raw Wastewater

Table 3 shows the mean water use as well as raw BOD_5 and SS wastewater loads from meat-packing plants. The two plants showing the lowest mean values for BOD_5 and SS are 8A and 9A with values of 10.2 and 8.1 kilograms BOD_5 per 1,000 kilograms and 10.0 and 8.4 kilograms SS per 1,000 kilograms live weight killed (LWK), respectively. Another plant, 1A, even though the mean BOD_5 and SS loads are not quite as low, does exhibit a variability that is minimal as can be seen by the standard deviations. At the other end of the scale are plants 3A and 7A with raw wastewater loads of 23.7 and 18.0 kilograms BOD_5 per 1,000 kilograms LWK and 17.7 and 14.4 kilograms SS per 1,000 kilograms LWK, respectively. Figures 1 and 2 show probability curves developed to graphically show the variability of the effluent.

It is difficult to pinpoint the reasons for the lower wasteloads without conducting an in-plant survey; therefore, conclusions have to be drawn based on the processing plant raw wasteload. For the above plants, one feature that might explain the differences is water use. In Table 3, plants 1A, 8A, and 9A, the three plants with the lowest water use for Category II, are also the ones mentioned above exhibiting the least raw wastewater load. Plant operations that could contribute toward this lower water use are better housekeeping practices and making use of dry cleanup prior to washdown. Another significant factor in water use reduction is the installation of high pressure nozzles on water outlets.

Meat: Final Effluent

Results of different treatment system employed in the meat-packing industry are presented in Table 4. All make use of a biological secondary system, either an anaerobic-aerobic lagoon system or an anaerobic contact process followed by aerobic lagoons.

As can be seen from the aforementioned table and Figure 3, comparing the results with the effluent limitations presented previously, only one of the plants could not meet the 1977 mean BOD_5

Table 3. RAW WASTEWATER CHARACTERISTICS

Plant	Effluent guidelines category	BOD$_5$[a]				SS[a]				Water use[c]
		Mean	Max.	Std. dev.	N[b]	Mean	Max.	Std. dev.	N	
1A	II	10.7	18	3.8	45/26	12.8	24	4.5	46/26	4.38 (525)
3A	II	23.7	33	4.9	34/12	17.7	27	3.1	35/12	15.60 (1,870)
4A	III	12.0	23	7.8	49/37	13.0	27	13	48/37	8.29 (993)
7A	II	18.0	45	10.6	33/17	14.4	36	10	30/17	9.27 (1,111)
8A	II	10.2	21	5.3	91/24	10.0	21	6.4	91/24	7.89 (946)
9A	II	8.1	15	3.1	42/11	8.4	16	7.5	53/11	8.44 (1,012)

[a] Values in kg/kkg LWK.

[b] N = number of observations/number of months in observation period.

[c] Water use in m^3/kkg (gal./1,000 lbs).

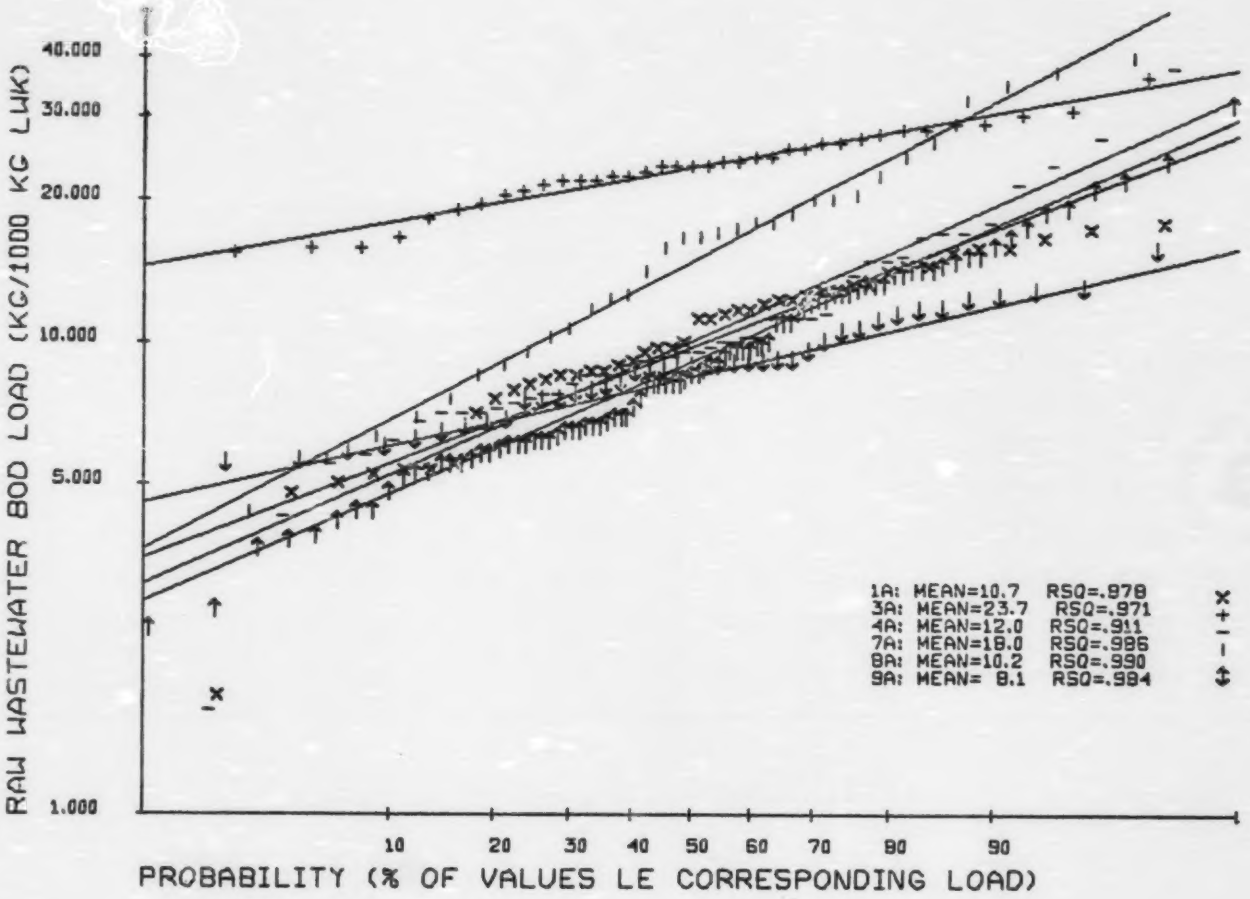

Figure 1. Log-Probability representation of meat-packing plant raw BOD$_5$ waste load.

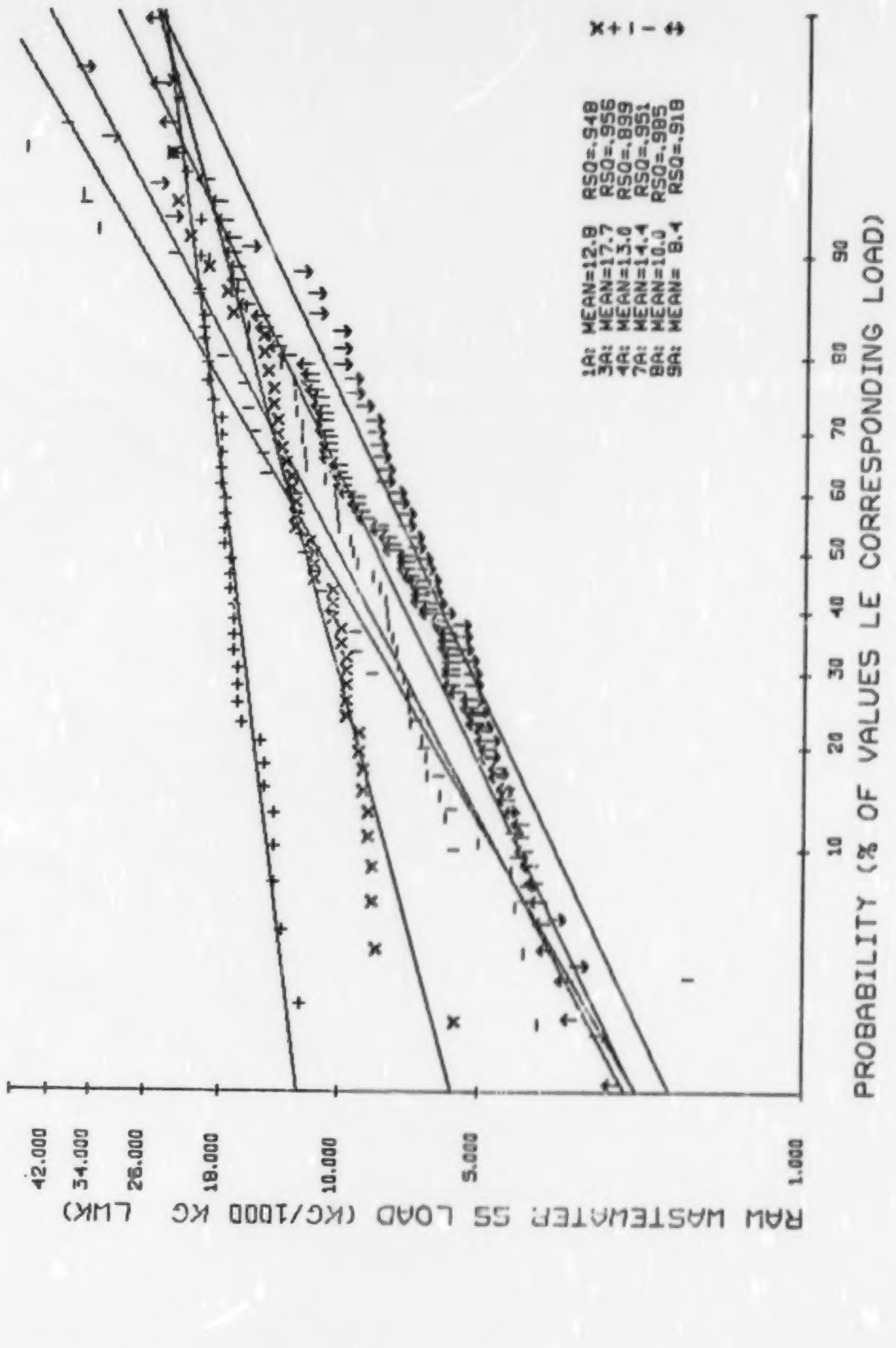

Figure 2. Log-Probability representation of meat-packing plant raw SS waste load.

Table 4. FINAL EFFLUENT CHARACTERISTICS

Plant	Effluent guidelines category	BOD_5[a]				SS[a]			
		Mean	Max.	Std. dev.	N[b]	Mean	Max.	Std. dev.	N
1A	II	0.13	0.58	0.13	43/27	0.33	2.31	0.37	46/27
3A	II	0.11	0.23	0.06	29/14	0.30	1.15	0.22	29/14
4A	III	0.16	0.55	0.10	32/36	0.67	1.95	0.47	28/36
7A	II	0.33	1.45	0.26	49/29	0.34	1.52	0.34	46/29
8A	II	0.14	0.46	0.10	92/24	0.43	1.55	0.32	92/24
9A	II	0.21	0.62	0.15	42/11	0.44	1.56	0.31	53/11

[a] Values in kg/kkg LWK

[b] N = number of observations/number of months in observation period.

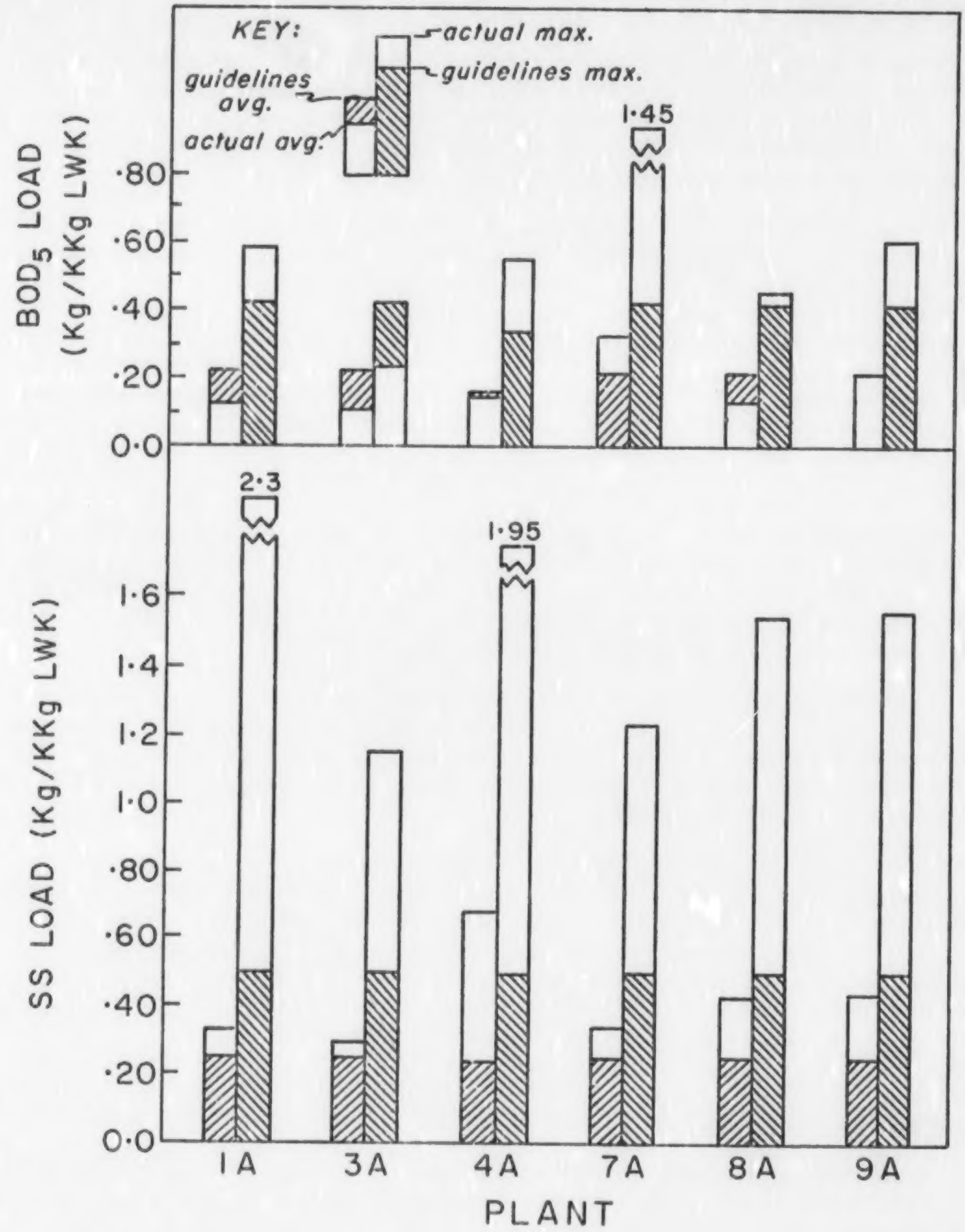

Figure 3. BOD$_5$ and SS actual versus 1977 guidelines 30-day average and daily maximum.

limits for its respective category and the maximum value was exceeded by five of the six. Figures 4 and 5 show probability curves developed to graphically show the BOD_5 variability of the effluent.

From Figures 3, 6, and 7, it can be seen that of the plants under consideration in this evaluation, none were able to meet either the 1977 mean or maximum suspended solids limits. Plants 1A, 3A, and 7A were closest to meeting the 0.25 kilograms per 1,000 kilograms LWK average limit, but none were near the established maximum value.

It should be noted that the average reported for each of the plants is a long-term average and not the maximum average for a 30-day period as specified in the guidelines. Because past monitoring policies were not established to meet the present system of effluent limitations, it was believed that reporting the data as a maximum average for a 30-day period did not truly reflect the capabilities of the treatment system. This was considered, but in some cases with infrequent sampling, the maximum average for a 30-day period approached the maximum daily value. In other cases, with more infrequent sampling, the maximum average for a 30-day period was in fact less than the long-term average.

The treatment system employed by plant 3A produced the lowest mean and maximum BOD_5 and suspended solids loads of the six meat-packing plants. This system consisted of an anerobic contact process and anaerobic-aerobic stabilization ponds. As mentioned previously, all others made use of an anaerobic-aerobic lagoon system.

Since there is a lack of diversity and number in the type of treatment system employed, no attempt is made to judge one system type better than another. Of the ones represented here, the ability of one to perform more effectively than the other is assumed then to be based on the operation of the plant.

An attempt was made to determine the cause of the occasions when the maximum allowed limits were exceeded. This was done using what information was available in regard to weather conditions and plant processes. The extent of the data varied widely from plant to plant. In some cases, when data permitted, an attempt was made to determine if the treatment plant was operating under normal loading or if some in-plant upset occurred which might affect the treatment system. Weather data, extremes in temperature and periods of high rainfall were variables for which data was more readily available that might aid in drawing some conclusion as to the operation of the treatment plant.

Beginning with plant 1A and making use of the basic data, events of high effluent load, both BOD_5 and suspended solids, are presented when available in Table 5 with an explanation of the prevailing operating conditions.

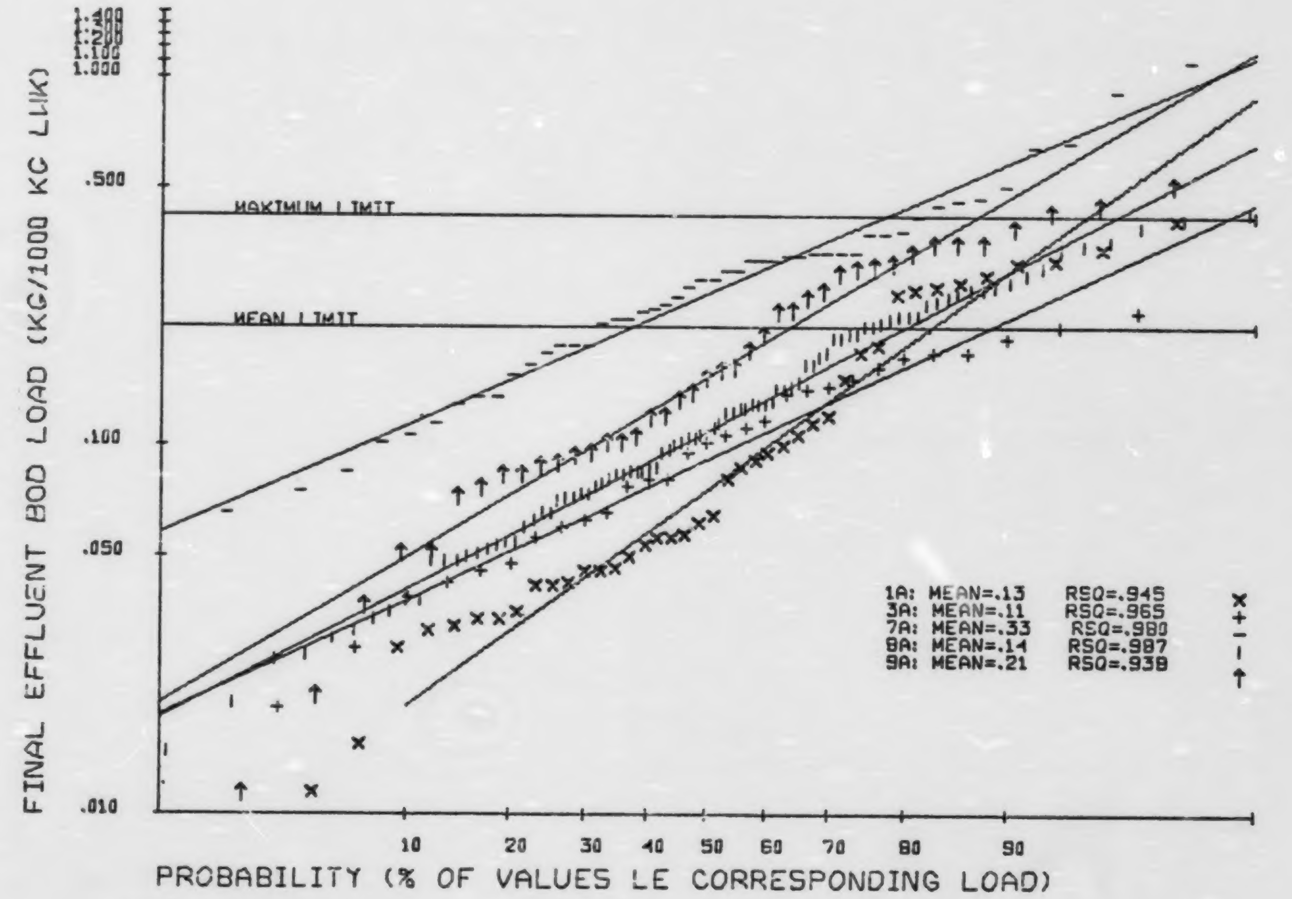

Figure 4. Log-Probability representation of meat-packing plant final effluent BOD_5 waste load, Category II plants.

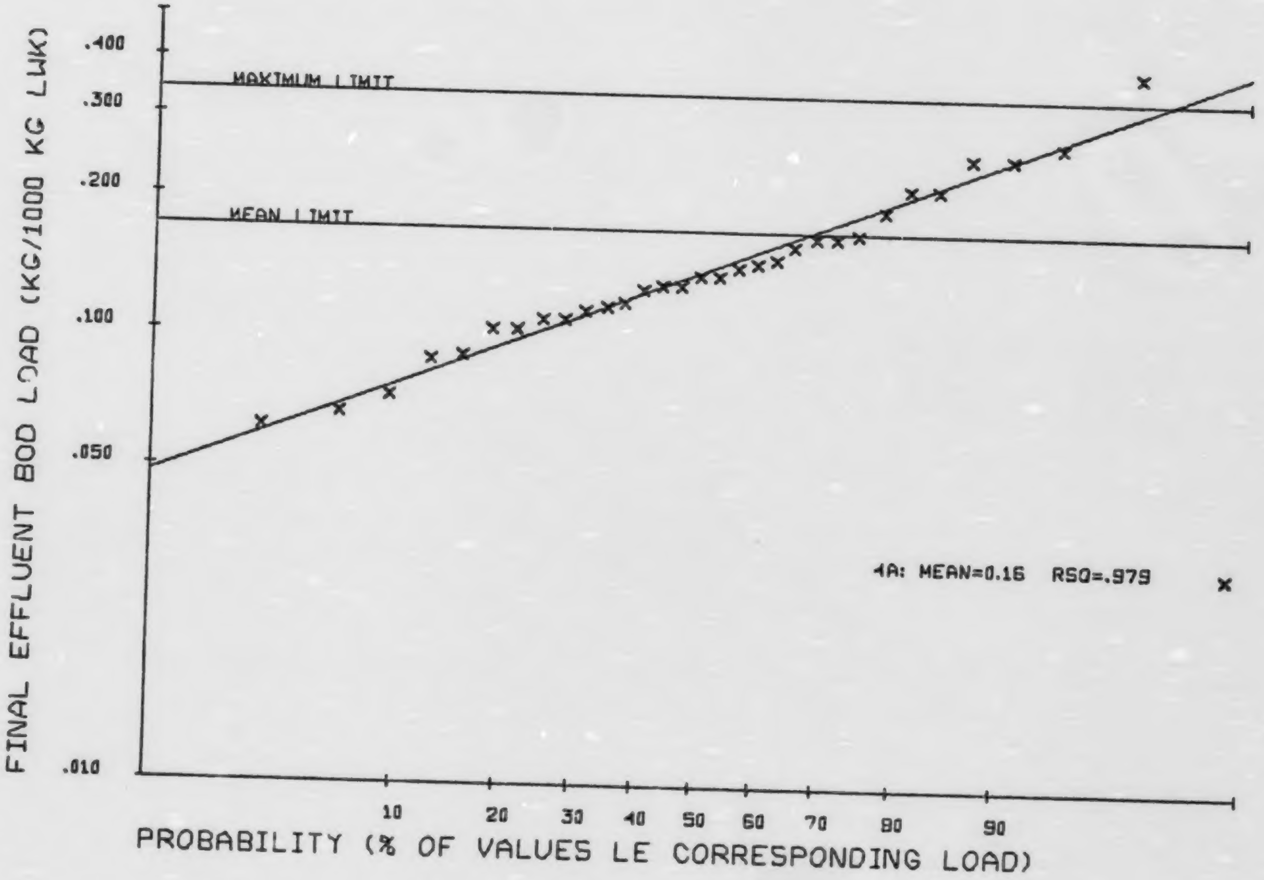

Figure 5. Log-Probability representation of meat-packing plant final effluent BOD_5 waste load, Category III plants.

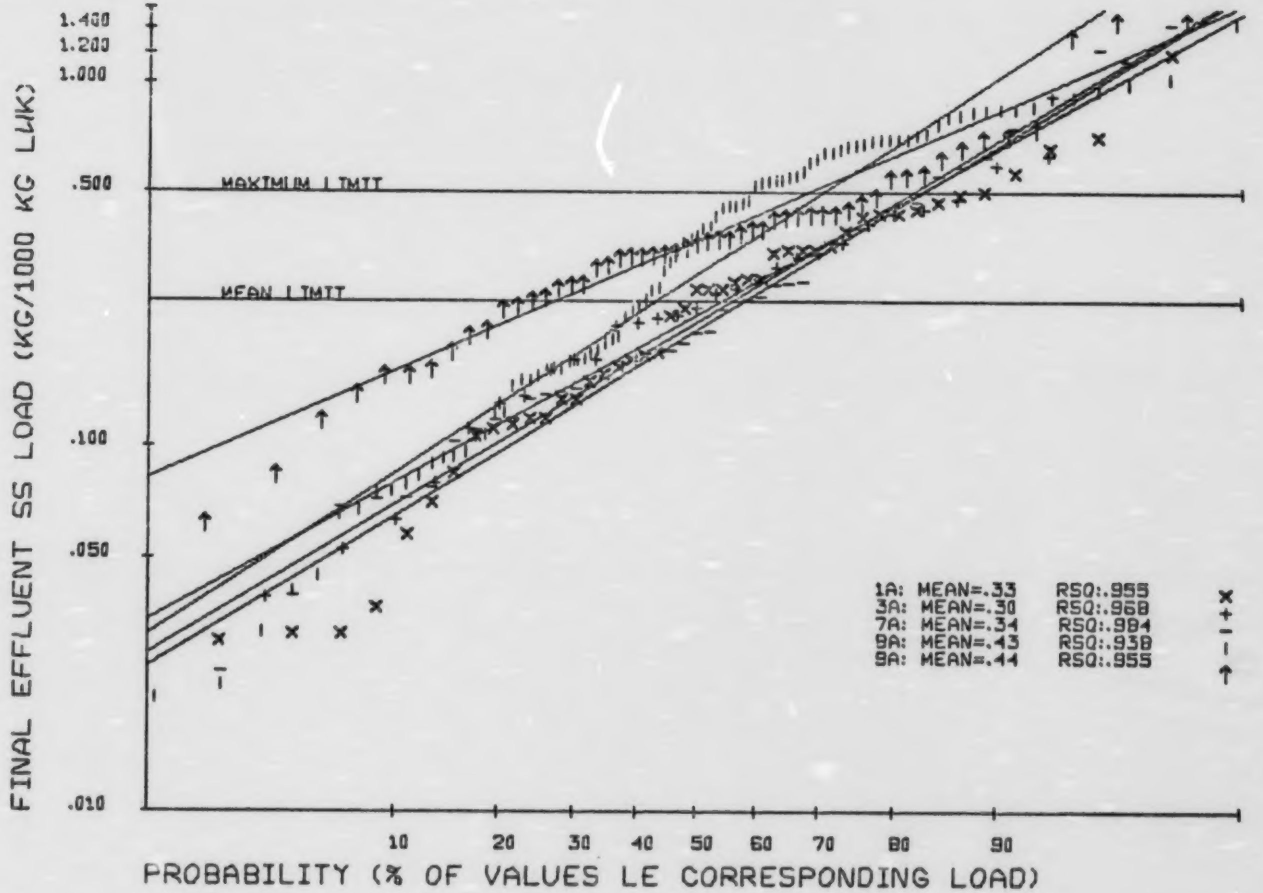

Figure 6. Log-Probability representation of meat-packing plant final effluent SS waste load, Category II plants.

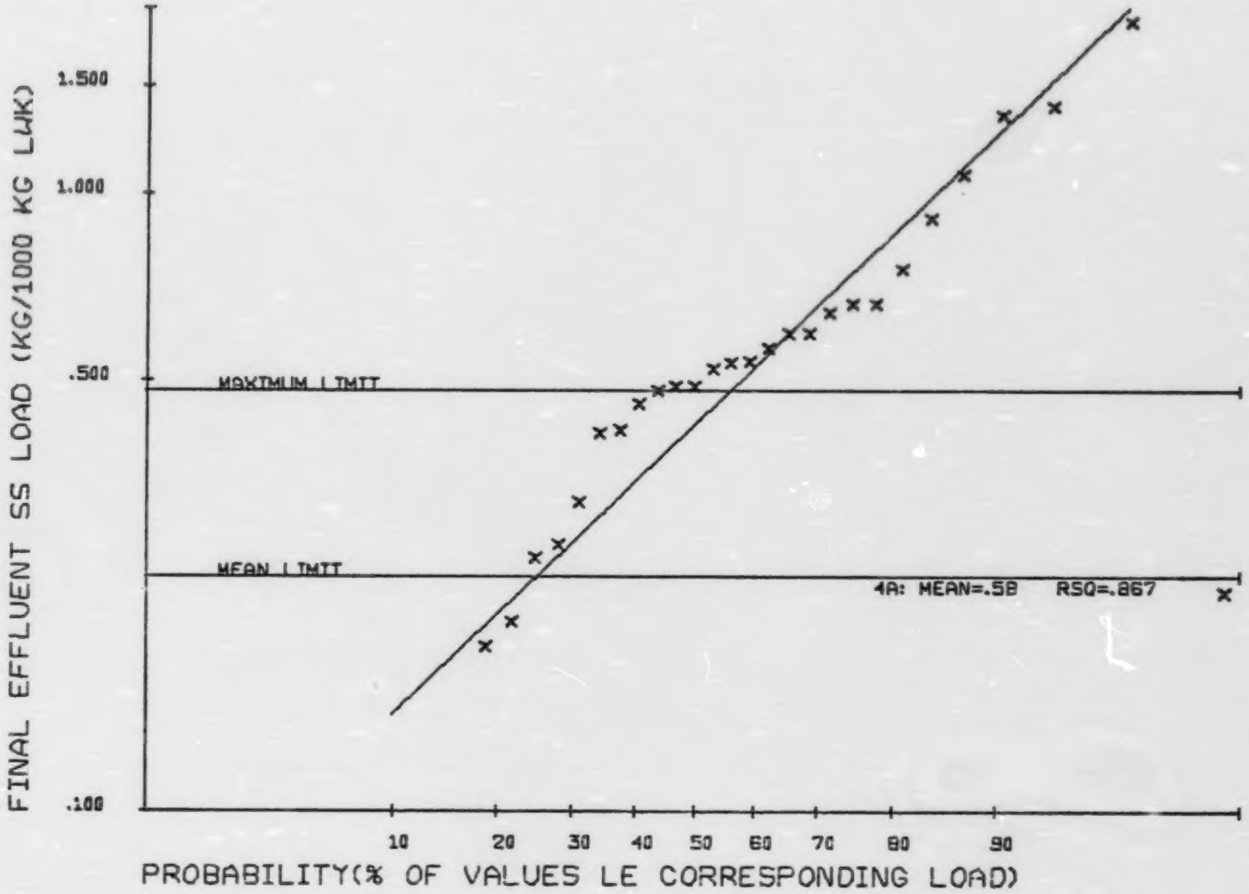

Figure 7. Log-Probability representation of meat-packing plant final effluent SS waste load, Category III plants.

Table 5. HIGH EFFLUENT LOAD OPERATING CONDITIONS

Plant	Effluent parameter	Date	Condition
1A	BOD_5	02/10/72	Period of sub-zero temperature, snow, and treatment plant overloaded.
	SS	02/24/72 03/09/72	Temperature near or below freezing, no overload.
4A	BOD_5	05/17/71	BOD_5 70 mg/l (20 mg/l > influent to final lagoon), flow and production normal.
		04/24/74	BOD_5 50 mg/l, second highest reported between 03/71 and 04/74.
	SS	05/17/71	SS 250 mg/l (200 mg/l > influent to final lagoon).
		04/17/72	SS 240 mg/l (110 mg/l > influent to final lagoon).
7A	BOD_5	01/25/73	Final flow > normal.
		07/13/73	Final flow > normal.
		05/24/74	Final flow > normal.
	SS	06/20/72	Rain, final flow normal.
		10/24/72	2" rain in previous 2 days, high flow, SS 133 mg/l.
		04/23/74	2½" rain, high flow, SS 140 mg/l.
8A	BOD_5	05/11/72	Rain, final flow > normal.
		11/08/72	Flow > normal.
		11/15/72	Flow > normal.
	SS	05/04/72	1" rain, flow > normal.
		06/15/73	Flow > normal, SS 136 mg/l.

From looking at those conditions, it is assumed that extremes in weather affected the performance of the lagoon systems used in the plants. For plants 1A, 7A, and 8A, all periods of ineffective operation coincided with either unusually cold weather or periods of high rainfall which produced an effluent flow greater than normal. These unusual operating conditions account for the occasions when the established 1977 effluent limitations were exceeded.

Table 6 shows the frequency of occurrence of values less than or equal to the 1977 mean and maximum effluent limitations based on the predicted curves of Figures 4 through 7. Plants 1A, 3A, and 7A are the only ones that might be capable of meeting the mean or 30-day average limitation for suspended solids. Of these plants the maximum limitation can only be met up to 85 percent of the time. The other 15 percent would be out of compliance.

Poultry: Raw Wastewater

Table 7 shows the mean raw BOD_5 and SS wastewater loads from poultry processing plants. Raw wastewater quality data was very limited with only two of the plants having BOD_5 data and one with SS data. The two, both broiler processing plants, were quite different in terms of raw waste load, 6.4 versus 36.7 kilograms per 1,000 kilograms LWK. Figures 8 and 9 show the variability of the raw waste load on a proability basis. One factor that would account for part of the variation in the load between the two plants is that plant 2B does not engage in further processing or rendering. However, the low wastewater load of plant 2B should merit further attention. Shown also in Table 7 is the water use by the four poultry processing plants in this study. Carawan et al.[2] concluded that lower water use in a poultry processing plant reduces the raw wastewater load. Plant 2B instituted a water conservation program in which the use dropped from approximately 42 to 26 liters per bird. Water reduction measures consisted of an employee awareness program, daily inspections, elimination of piping leaks and the use of hoses where possible, and automatic shut off valves on essential hoses. Supply lines were equipped with valves to allow for flow regulation. Dry cleanup was practiced prior to washdown with a portable high pressure cleaning system. Lastly, chill vat water was recycled for reuse in the scalder. It is assumed, based on Carawan's earlier conclusions, that the water conservation measures undertaken by plant 2B are largely responsible for the lower raw waste load of the plant.

As an additional note plant 3B, the other plant with low water use, instituted water conservation measures. These consisted of a water pressure reduction from 414 to 138 kilonewton per square meter (60 to 20 pounds per square inch), installation of spray type hand washers, use of

Table 6. FREQUENCY OF OCCURRENCE OF VALUES $\leq$ 1977 EFFLUENT LIMITATIONS (From predicted curves, in percent)

Plant	BOD_5		SS	
	Mean	Max.	Mean	Max.
1A	82	93	56	82
3A	89	100	57	82
4A	68	96	25	55
7A	38	78	54	82
8A	80	95	44	71
9A	64	87	28	68

Table 7. RAW WASTEWATER CHARACTERISTICS

Plant	Effluent guidelines category	BOD_5[a]				SS[a]				Water use[c]
		Mean	Max.	Std. dev.	N[b]	Mean	Max.	Std. dev.	N	
2B	Broiler	6.4	15	2.2	62/8	12	41	7.0	61/8	26.0 (6.9)
3B	Duck	-	-	-	-	-	-	-	-	26.7 (7.06)
5B	Broiler	-	-	-	-	-	-	-	-	67.4 (17.8)
6B	Broiler	36.7	52	11.8	10/5	-	-	-	-	42.8 (11.3)

[a] Values in kg/kkg LWK.

[b] N = Number of observations/number of months in observation period.

[c] Water use in liters/bird (gal./bird).

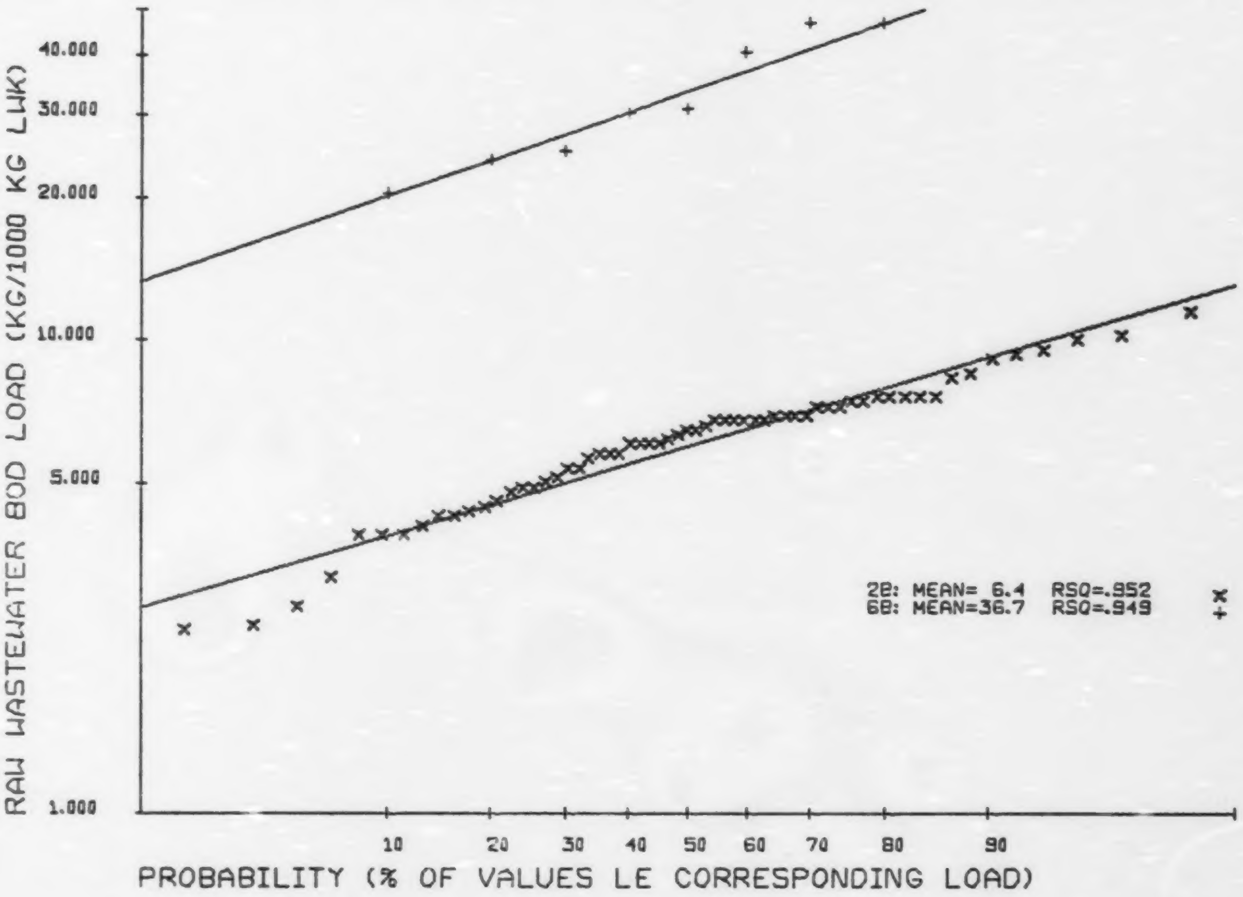

Figure 8. Log-Probability representation of poultry processing plant raw BOD_5 waste load.

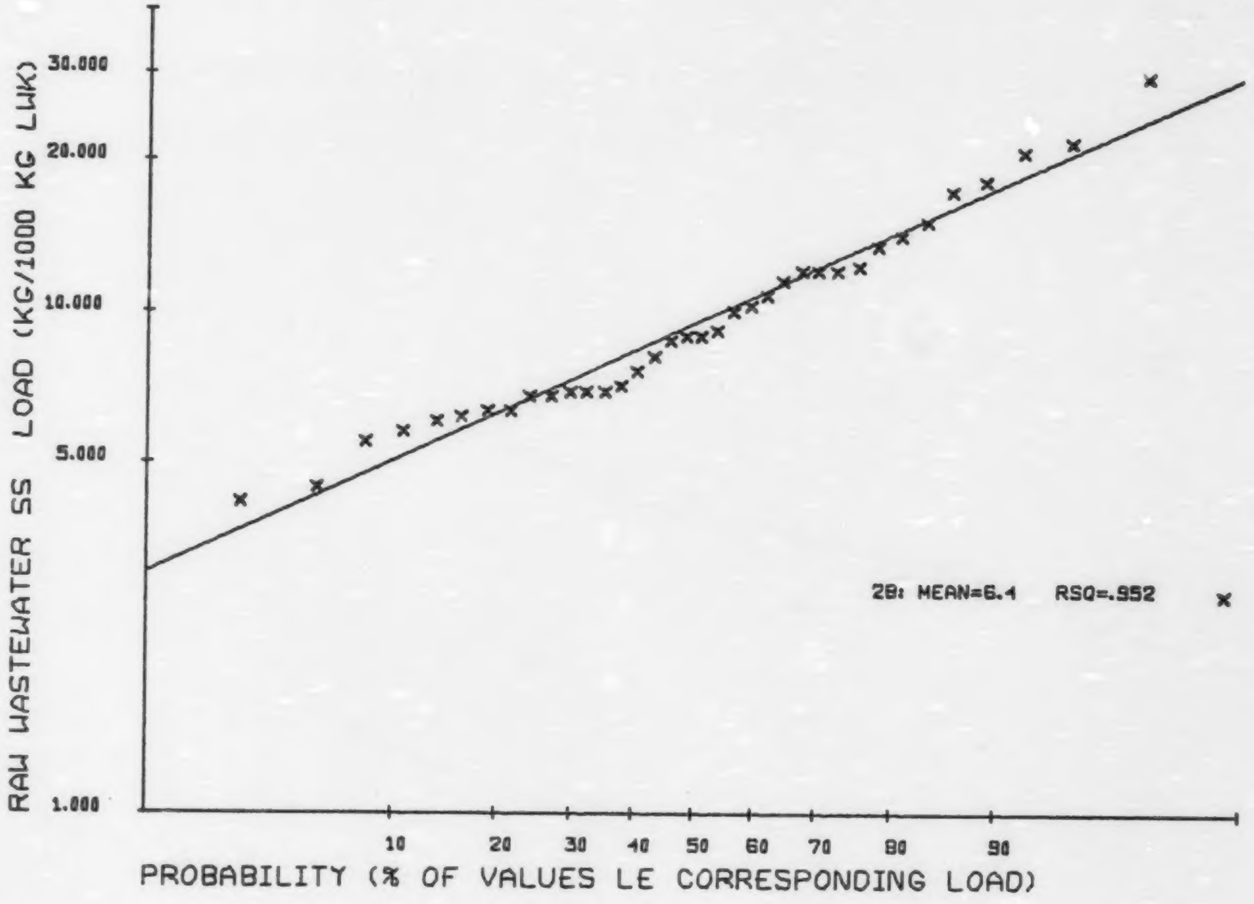

Figure 9. Log-Probability representation of poultry processing plant raw SS waste load.

high pressure-low water systems in clean-up, and cutoff in flow-through system to stop water flow when lines are not running.

Poultry: Final Effluent

Table 8 summarizes the results of treatment systems employed in the poultry processing industry. Biological secondary systems used are aerated lagoons, anaerobic-aerobic lagoons, and activated sludge.

Due to the guidelines regarding effluent limitations not being finalized at the time of this writing, the results obtained by the plants in this study are compared to the 1977 values recommended by the contractor to EPA. These are not to be taken as a limit, but only a value from which to compare the results obtained here. As with the meat-packing plants, the averages presented are the long-term averages and not the maximum average for a 30-day period.

Of the four plants presented, two of the recommended categories are represented. These are the duck processor and the broiler processor with one of the broiler processors (6B) engaged in further processing and rendering.

Table 8 and Figure 10 show that two of the broiler processors and the duck processor would meet the average BOD_5 limits. The maximum daily value of the plants within the recommended average varies in the range of 1.8 to 4.2 times the mean obtained by these plants. Based on the recommended averages of 0.46 and 0.77 kilograms BOD_5 per 1,000 kilograms LWK for plants 2B and 3B, respectively, the maximum would be 3.7 and 0.73 times the average. Plant 3B is a case where the values are so low as to make the maximum less than the recommended average. Plant 6B, with the maximum 4.1 times its average or 1.7 times the recommended average is a special case since this plant also handles further processing and rendering operations. Though it would meet the more stringent BOD_5 limit for a normal broiler processing plant, its mean value of 0.29 kilograms per 1,000 kilograms LWK would readily be in compliance with the 0.72 kilograms per 1,000 kilograms LWK recommended limit based on an adjustment factor for the ancillary operations. Figures 11, 12, and 13 show the probability curves developed to graphically show the BOD_5 variability of the effluent for these plants.

Table 8 also shows the suspended solids levels obtained by all the plants except 6B and these are compared to the recommended limits in Figure 10. Only one of these (3B) was able to meet the recommended limits and it did so readily, with the maximum of 1.35 kilograms per 1,000 kilograms LWK being greater than the recommended average of 0.90 kilograms per 1,000 kilograms LWK by a factor of 1.5. Figures 14 and 15

Table 8. FINAL EFFLUENT CHARACTERISTICS

Plant	Effluent guidelines category	BOD$_5$[a]				SS			
		Mean	Max.	Std. dev.	N[b]	Mean	Max.	Std. dev.	N
2B	Broiler	0.40	1.7	0.35	102/11	1.0	3.5	0.79	102/11
3B	Duck	0.18	0.56	0.11	46/27	0.32	1.35	0.23	47/27
5B	Broiler	0.67	1.2	0.27	36/5	1.61	4.8	1.33	28/5
6B	Broiler	0.29	1.2	0.24	68/8	-	-	-	-

[a] Values in kg/kkg LWK.

[b] N = Number of observations/number of months in observation period.

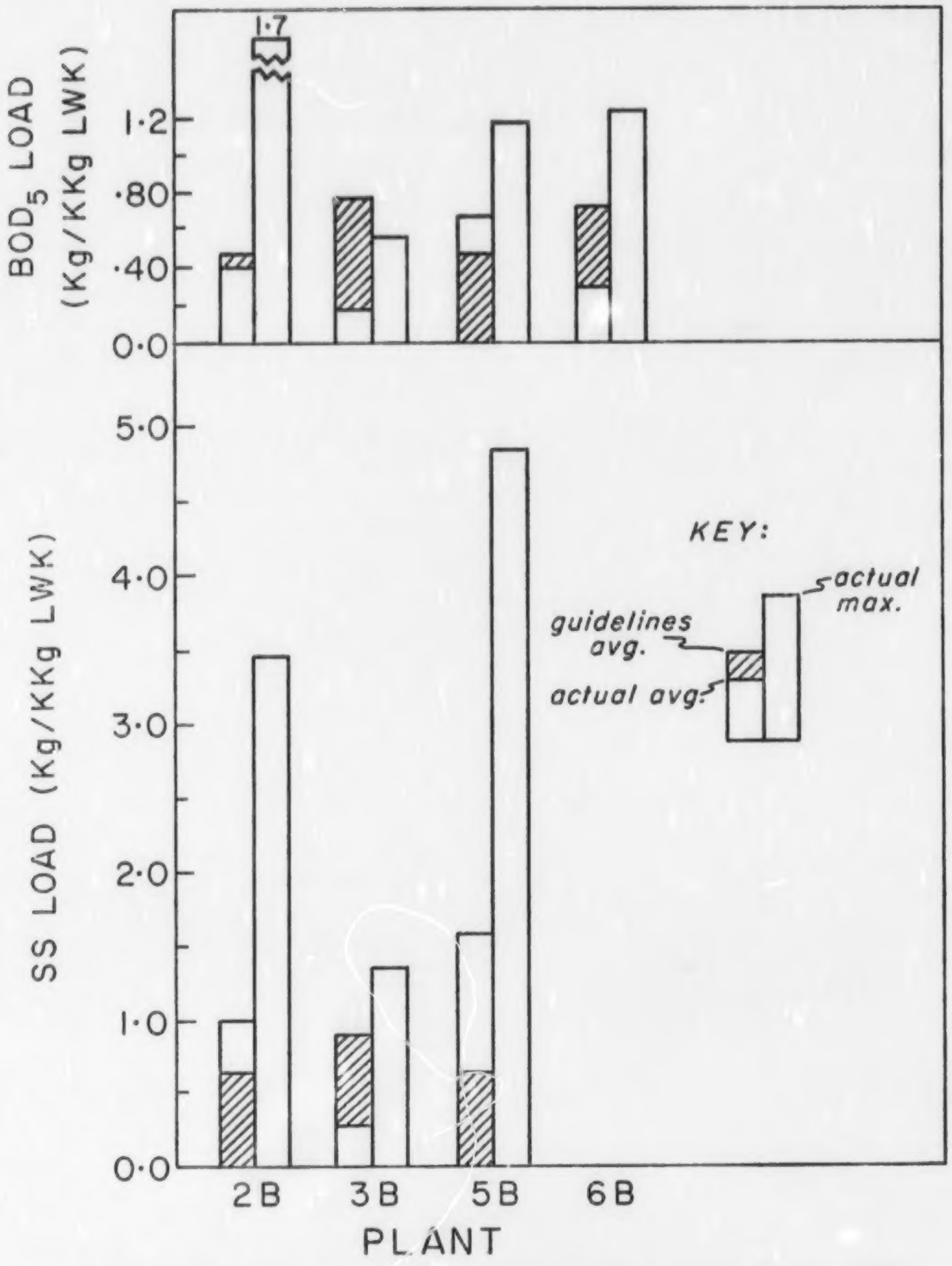

Figure 10. BOD$_5$ and SS actual mean and maximum versus 1977 recommended guidelines mean.

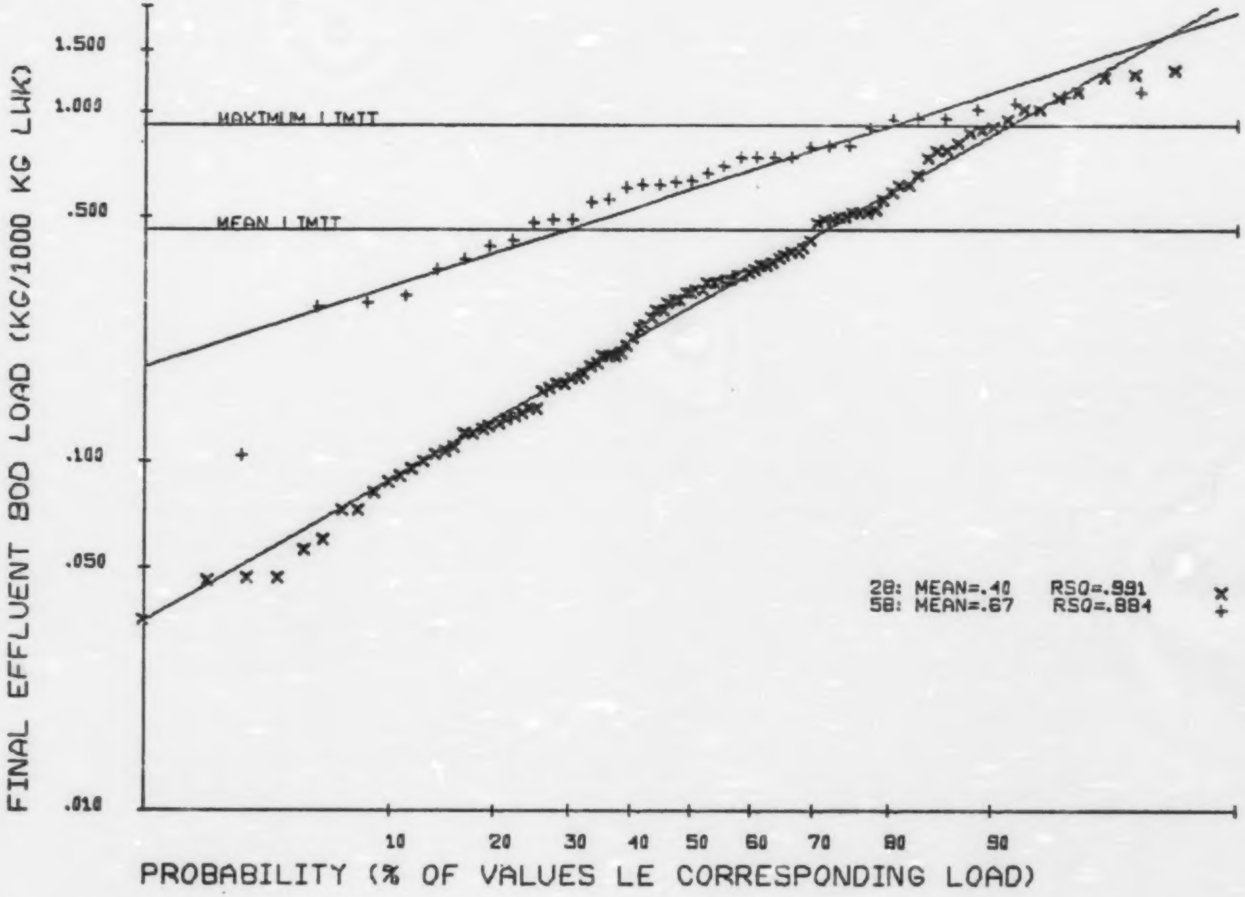

Figure 11. Log-Probability representation of poultry processing plant final effluent BOD_5 waste load, broiler category.

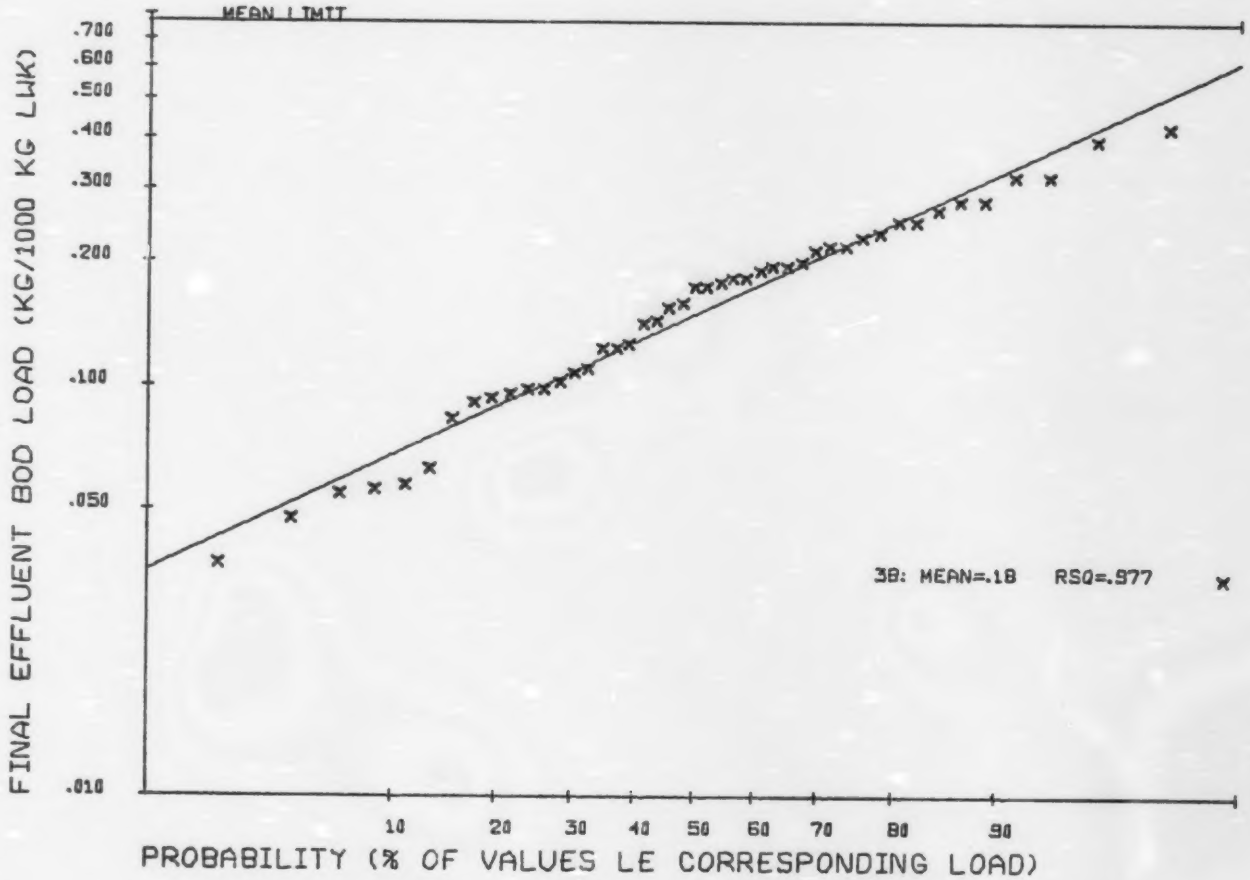

Figure 12. Log-Probability representation of a poultry processing plant final effluent BOD_5 waste load, duck category.

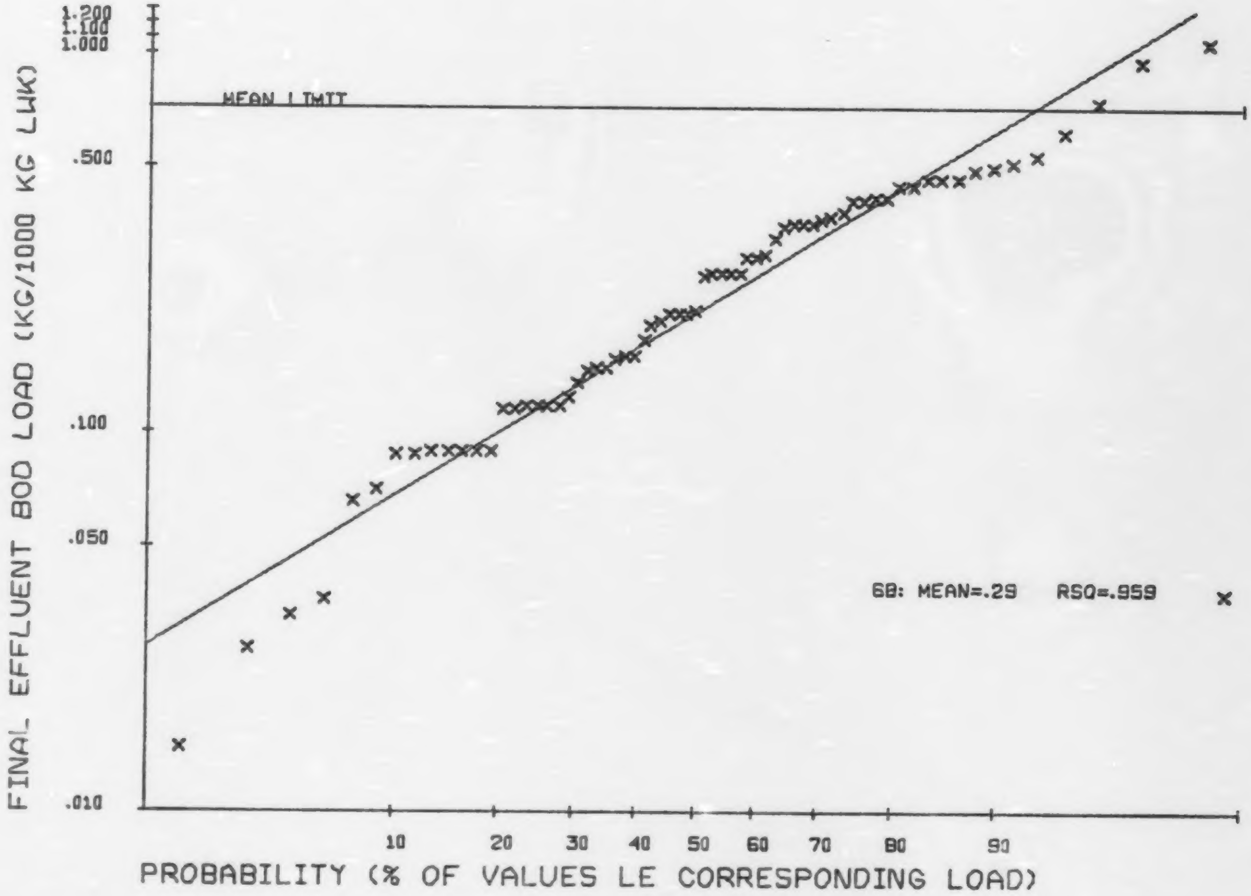

Figure 13. Log-Probability representation of poultry processing plant final effluent BOD_5 waste load, broiler category plus further processing and rendering.

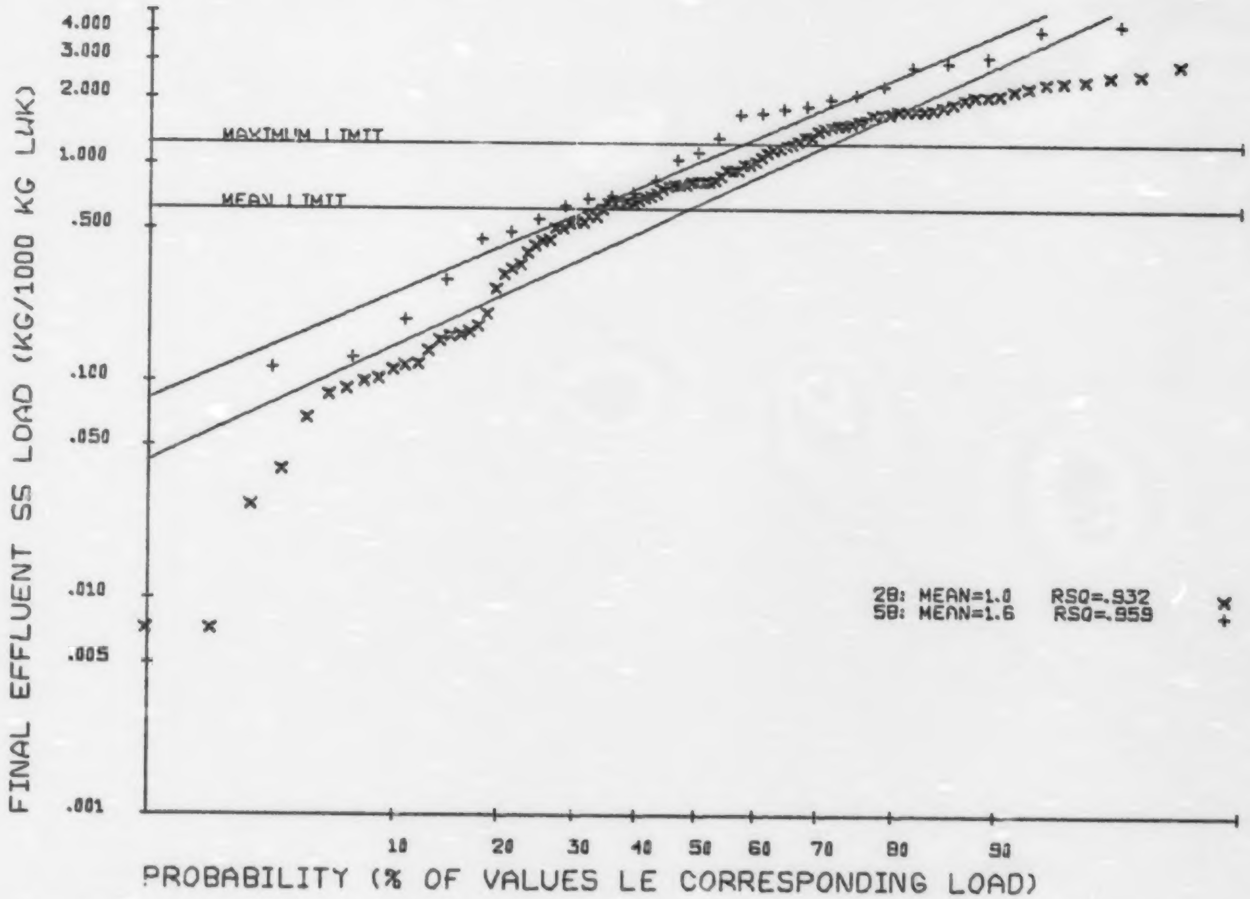

Figure 14. Log-Probability representation of poultry processing plant final effluent SS waste load, broiler category.

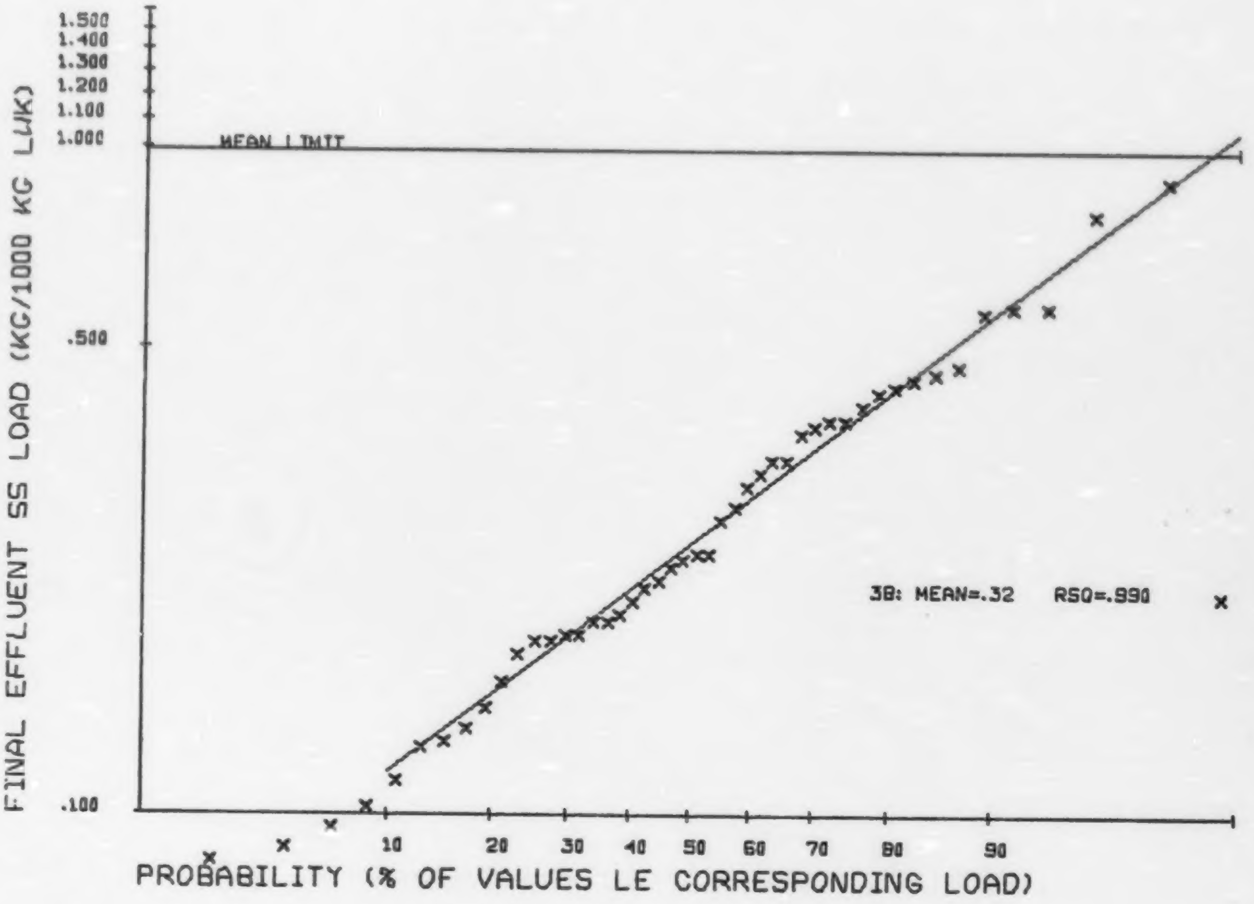

Figure 15. Log-Probability representation of poultry processing plant final effluent SS waste load, duck category.

graphically show the suspended solids variability by the use of probability plots.

The treatment system employed by plant 3B consists of in-plant screening followed by three aerobic lagoons in series. This plant also made use of extensive water conservation practices as mentioned earlier. Plant 6B, producing a low BOD_5 load, also is capable of effective suspended solids treatment. Sufficient data was not available to properly evaluate it, but it has been able to produce an effluent suspended solids of 5 milligrams per liter. This system consists of a grease trap, wet well, holding tank, chemical mixing, flotation, activated sludge, two-parallel microstrainers, and a chlorine contact tank.

As with the meat-packing plants an attempt was made to determine the cause for the extremely high values. Information on weather conditions and plant processes is not as complete as meat-packing plants and there is adequate data on only one plant, 3B. Table 9 presents the periods of high effluent loads with an explanation of the prevailing operating conditions. In all cases of high effluent BOD_5 or SS loads there also existed an unusual weather condition, either heavy rainfall or high wind. This plant has since made provisions to eliminate rainfall runoff from its treatment system.

Table 10 shows the frequency of occurrence of values less than or equal to the 1977 mean effluent limitations based on the predicted curves. Plants 2B, 3B, and 6B are capable of meeting the mean BOD_5 effluent limitation with at least 72 percent of their values being lower than the recommended mean. For 3B and 6B, this values increases to 92 and 100 percent, respectively. With respect to suspended solids, only 3B falls within the recommended average greater than 5 percent of the time, in this case 100 percent. It is noted again that there was not sufficient data to evaluate plant 6B for SS.

Winter-Summer Variation of Treated Effluent

Both the meat-packing and poultry processing plants were tested for any winter versus summer variation. The summer being classified as May through October. The means and variances were tested for equality at a confidence level of 95 percent. Table 11 shows the results of the statistical tests performed on the means and variances. No clear pattern could be detected for the variation. Plants 1A and 4A, which both meet the 1977 BOD_5 limits but not the suspended solids limits, were the only meat-packing plants meeting the test for the equality of the means. Plant 4A also meets the criteria for equality of the variances at a 95 percent confidence level. All other meat-packing plants fail

Table 9. HIGH EFFLUENT LOAD OPERATING CONDITIONS

Plant	Effluent parameter	Date	Condition
3B	BOD_5	08/09/72	Heavy rain, high runoff.
		06/25/73	Heavy rain, muddy outlet.
		09/05/73	High discharge, affected by summer rainfall.
	SS	08/09/72	Heavy rain, high runoff.
		08/28/72	High wind, SS > 100 mg/l.
		10/09/72	Heavy rain.

Table 10. FREQUENCY OF OCCURRENCE OF VALUES $\leq$ RECOMMENDED 1977 EFFLUENT GUIDELINES
(From predicted curves, in percent)

Plant	Mean BOD_5	Mean SS
2B	65	35
3B	100	100
5B	25	25
6B	100	-

Table 11. RESULTS OF STATISTICAL TESTS FOR WINTER-SUMMER EQUALITY OF MEANS AND VARIANCES[a]

Plant	Results
1A	1010
4A	1111
7A	0000
8A	0101
9A	0100
2B	1111
6B	11--

[a] Tests conducted at a 95% confidence level; "1" implies meeting the test, "0" does not; first two digits relate to BOD_5 mean and variance, second two are for SS.

the test except for 3A which did not have sufficient data for comparison.

Plants 2B and 6B, the two poultry processors tested for any winter-summer variation, both met the tests for equality of the means and variances with respect to any BOD_5 or suspended solids variation except for 6B which had no suspended solids data. With respect to ability to meet the 1977 recommended effluent limitations, plants 2B and 6B readily met the BOD_5 guidelines, but 2B is not able to meet the suspended solids limits.

SUMMARY AND CONCLUSIONS

The results on the raw waste load tend to support conclusions reached by Carawan[2] that lower water use reduces the raw waste load. Plants that instituted a water use reduction program also had a corresponding wastewater load reduction.

On a long-term basis, the meat-packers appear to be capable of meeting the 1977 limitations on BOD_5, but for suspended solids the maximum daily value is critical. Of the six plants in this study, the most effective one exceeded the maximum suspended solids limitation 15 percent of the time.

Based on the recommended guidelines for the poultry processing industry, there are plants in existence that can readily meet the 1977 BOD_5 and suspended solids limitations. The 1983 BOD_5 average limits are being met by two of the plants, a duck processor and the broiler or chicken processor that engages in further processing and rendering. The duck processor is also able to meet the 1983 maximum BOD_5 and average SS limitations assuming the maximum limit will be established as two times the average.

For both the meat-packer and poultry processor, periods of high effluent load coincided with periods of abnormal weather conditions. In the case of the meat-packing plants, where sufficient data was available, all occasions of exceeding the maximum limitation were accompanied by severe weather conditions.

Of the plants evaluated in this study, there is no conclusive evidence as to the variability of the effluent with respect to winter-summer. Overall performance of a treatment plant appeared to have no effect on the variability with respect to the seasons.

Due to lack of diversity and number, it was not possible to comparatively evaluate the effectiveness of the treatment systems. For the meat-packing industry, both treatment systems of an anaerobic contact system followed by aerobic stabilization ponds and anaerobic-aerobic lagoon systems were similarly effective. For the poultry processing industry, effective treatment was provided by three different biological secondary systems: aerated lagoons, anaerobic-aerobic lagoons, and activated sludge. The wastewater management systems employing the aerated lagoons (three in series) and the activated sludge were more readily able to meet the recommended effluent limitations. The latter system consisted of a grease trap, wet well, holding tank, chemical mixing, flotation, activated sludge, two-parallel microstrainers, and a chlorine contact tank.

Inferences drawn from the plots of the effluent load versus frequency for the meat-packing and poultry plants are that in order to stay within the maximum limitations, an average less than the 30-day average limit will be necessary. This is due to the fact that the maximum value of the effluent load is greater than twice the average load. Some plants, as in the case of BOD_5 for 6B, even though the maximum value is greater than two times the mean, both fall within the average and maximum limits due to the low average value. Since a plant such as this is weighted more heavily in the lower range of values, it is to be expected that the maximum would be greater than two times the average due to the range of effluent loads inherent to the system.

Relating the results to the enforcement of the established guidelines would lead one to question the enforceability of the maximum limit. Using the system of Plant 1A, the maximum allowed BOD_5 value was exceeded only one time in 43 samples. For monthly or weekly samples this would result in a probability of sampling on a day that the maximum was exceeded of only 2×10^{-9} and 5×10^{-5}, respectively. See Appendix for calculation. In any plant that exceeded this limit frequently enough to cause enforcement action, the high results would increase the mean such that enforcement of these extreme values would be covered in the mean.

This leads to a system proposed for one by Popel[3] in which a combined standard would be established with a set limit and an allowed probability of exceeding it. To illustrate this concept, the results of plant 6B are plotted again in Figure 16 as in Figure 13, except this time using an arithmetic scale. This more effectively shows the point at which the treatment efficiency falls off. The combined standard would set the limit at this point, or the 90 percent level in this case. This would allow for the few occasions of the less effective plant operation that might be due to weather conditions, but in actuality would closely represent the true performance of the treatment system for a major percentage of the time.

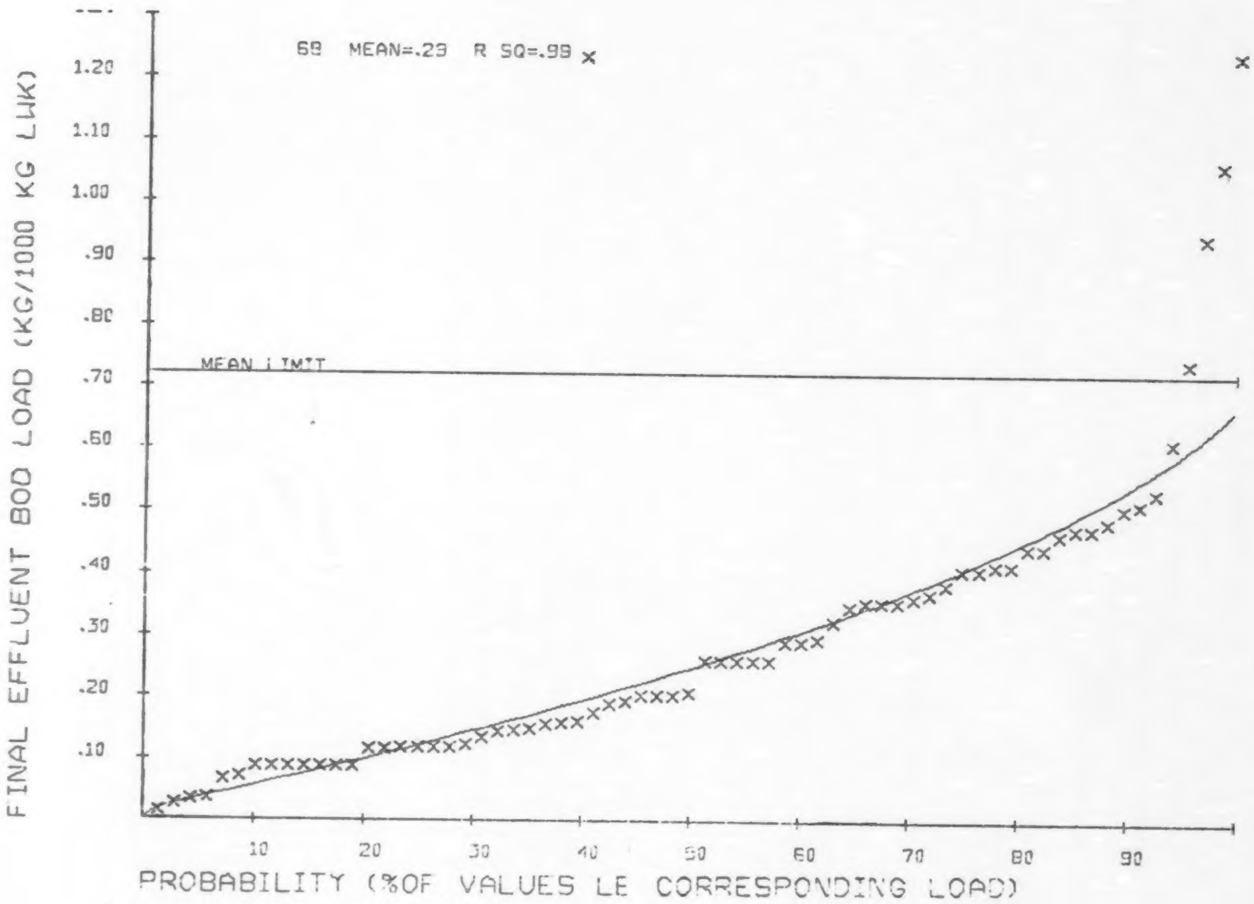

Figure 16. Arithmetic representation of Plant 6B final effluent BOD_5 load and frequency of occurrence.

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APPENDIX

Equations Used for Calculation of Adjustment Factors for Plant 6B Poultry

For 1977 Discharge limitations:

Rendering

BOD_5: (0.15 kg BOD_5/kkg RM) (kkg RM/kkg/LWK)
SS: (0.17 kg SS/kkg RM) (kkg RM/kkg LWK)

Further Processing

BOD_5: (0.30 kg BOD_5/kkg FP) (kkg FP/kkg LWK)
SS: (0.35 kg SS/kkg FP) (kkg FP/kkg LWK)

For 1983 Discharge limitations:

Rendering

BOD_5: (0.07 kg BOD_5/kg RM) (kkg RM/kkg LWK)
SS: (0.10 kg SS/kkg RM) (kkg RM/kkg LWK)

Further Processing

BOD_5: (0.15 kg BOD_5/kg FP) (kkg FP/kkg LWK)
SS: (0.18 kg SS/kkg FP) (kkg FP/kkg LWK)

where: RM = amount of raw materials rendered on site
FP = amount of further processing done

BOD_5 (adjusted) = BOD_5 (recommended for subcategory) +
BOD_5 (rendering) + BOD (further processing)
SS (adjusted) = (calculate same as for BOD_5)

Calculation of Probability of Sampling the Occasion of Maximum Effluent Load

From Burr[4]

$$\begin{aligned} C(n,r) &= R(n,r)/P(r,r) \\ &= n!/r!(n-r) \end{aligned}$$

where

C(n,r) is the desired number of combinations of n different things r at a time,
P(n,r) is the number of permutations of n different objectives taken r at a time, and,
P(r,r) is the number of different order in which all of r objects may be drawn.

For the case of monthly sample, or 12 samples in 260 working days and a violation that occurs 1 in 43 (6 in 260) working days.

C(254,6) = number of 12-sample monitoring schedule that contain all 6 violations in a 260-day sampling period.
C(260,12) = number of 12-sample monitoring schedules in 260-day sampling period, and
P(6 violations) = C(254,6)/C(260,12)

Where P(6 violations) is the probability of sampling the six violations.

C(254,6) = 254!/6!(248!)
C(260,12) = 260!/12!(248)!

P(6 violations) = 2.28×10^{-9}

Similarly, for the case of weekly sampling, or 52 samples in 260 working days.

C(254,46) = 254!/46!(208)!
C(260,52) = 260!/52!(208)!

and,

P(6 violations) = 5.03×10^{-9}

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